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CONTROL OF ARTERIAL HEMORRHAGE BY A GELATIN SPONGE "CUFF" AND CHROMIC SURGICAL GUT SHEATH

A New Experimental Method

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THE RECENT experimental and clinical contributions in vascular surgery have stimulated an interest in this field which may lead to further widening of the scope of surgery. The "soluble rod" for arterial anastomosis which was described by Smith [1] was designed to simplify the suture technic which was developed chiefly by Carrel,[2] Horsley,[3] and others, for blood vessel anastomosis. The vitallium tubes which were introduced by Blakemore, Lord and Stefke [4] for vascular anastomosis and for restoring arterial defects by vein transplants represent a promising technical development in vascular surgery. The absorbable tubes composed of fibrin which were devised by Swenson and Gross [5] for blood vessel anastomosis represent another important development which overcomes a disadvantage of the vitallium tube in

From the Department of Surgery, The University of Chicago, School of Medicine.

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb. 21, 1947.

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1. Smith, S.: The Soluble Rod as an Aid to Vascular Anastomosis, Arch. Surg. **41**:1004 (Oct.) 1940; Studies in Experimental Vascular Surgery, Surgery **18**:627, 1945.

2. Carrel, A., and Guthrie, C. C.: Uniterminal and Biterminal Venous Transplantations, Surg., Gynec. Obst. **2**:266, 1906.

3. Horsley, J. S.: Surgery of the Blood Vessels, St. Louis, C. V. Mosby Company, 1915.

4. Blakemore, A. H.; Lord, J. W., and Stefke, P. L.: Restoration of the Blood Flow in Damaged Arteries, Ann. Surg. **117**:481, 1943.

5. Swenson, O., and Gross, R. E.: Absorbable Fibrin Tubes for Vein Anastomoses, Surgery **22**:137 (July) 1947.

children's surgery where it would obviously be desirable for the vascular channel to increase in size with the growth of the child. The operation for coarctation of the aorta reported by Gross [6] and the operation originated by Blalock and Taussig [7] for malformations of the heart with pulmonary stenosis or atresia and the anastomosis of the aorta to the pulmonary artery developed by Potts, Smith and Gibson [8] represent most valuable contributions to clinical vascular surgery. These operations were developed as a result of extensive experimental studies on animals in which the technics for these vascular anastomoses were worked out.

The concentration of most of the vascular injuries of the recent war in the hands of a relatively few experienced surgeons has given an impetus to this field of surgery. The reports on the management of vascular injuries, such as the extensive review by DeBakey and Simeone,[9] indicate that these injuries have been competently handled. However, in only a relatively small proportion of the acute arterial injuries has it been feasible to resort to suture, anastomosis or vein graft with the aid of vitallium tubes. The results in these cases from the standpoint of prevention of gangrene have not been especially satisfactory as compared with the cases in which ligation was done. There is obviously a place for some further study of the problem of repair of a damaged artery which would offer a more satisfactory means of restoring blood flow than having to resort to ligation in so many instances.

In view of the satisfactory results which were obtained in controlling hemorrhage from wounds of the vena cava and other veins in dogs by the gelatin sponge "patch" [10] it appeared plausible to attempt control

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6. Gross, R. E.: Technical Consideration in Surgical Therapy Coarctation of Aorta, Surgery **20**:1, 1946; Surgical Correction for Coarctation of the Aorta, ibid. **18**:673, 1945. Gross, R. E., and Hufnagel, C. A.: Coarctation of Aorta: Experimental Studies Regarding Its Surgical Corrections, New England J. Med. **233**:287, 1945.

7. Blalock, A., and Taussig, H. G.: The Surgical Treatment of Malformations of the Heart in Which There is Pulmonary Stenosis or Pulmonary Atresia, J.A.M.A. **128**:189 (May 19) 1945.

8. Potts, W. J.; Smith, S., and Gibson, S.: Anastomosis of Aorta to Pulmonary Artery, J.A.M.A. **132**:627 (Nov. 16) 1946.

9. DeBakey, M. E., and Simeone, F. A.: Battle Injuries of the Arteries in World War II, Ann. Surg. **123**:534, 1946.

10. Jenkins, H. P., and Janda, R.: Studies on the Use of Gelatin Sponge or Foam as a Hemostatic Agent in Experimental Liver Resections and Injuries to Large Veins, Ann. Surg. **124**:953, 1946.

of arterial hemorrhage with this new hemostatic agent.[11] A technic was devised which consisted of wrapping a "cuff" of dry compressed gelatin sponge about the wound in the artery and surrounding this with a sheath of chromic surgical gut. With this method, it was possible to control hemorrhage and restore blood flow in wounds of the aorta in experimental animals without having to resort to arterial suture. A preliminary report of this method has been made.[12]

EXPERIMENT

A series of 22 dogs were operated on under ether anesthesia and with aseptic technic. The aorta distal to the renal arteries was exposed by a midline or a transverse abdominal incision. The overlying peritoneum was incised and the aorta isolated from surrounding structures. It was necessary in most instances to ligate several of its small branches to permit mobilization. Rubber-covered bulldog clamps were applied above and below the point selected for the wound and then a scalpel was thrust through one or both walls of the vessel (fig. 1 *A*). When the proximal bulldog clamp was temporarily released, the hemorrhage which resulted could best be described as massive (fig. 1 *B*). The gelatin sponge available for these experiments was in the form of sheets approximately 3 inches by 4 inches by ½ inch (7.6 by 10.2 by 1.3 cm.). It had been previously heat sterilized and packaged in sealed glass jars by the manufacturer. A piece measuring about 1½ by 2 inches (3.8 by 5.1 cm.) was cut from the large sheet. This was then compressed with the fingers until it was pliable and could be rolled into the form of a tube. The gelatin sponge is rather brittle in the dry state and unless it is compressed cannot be rolled up. When moistened, it is more difficult to handle and rather friable. The smaller pieces of gelatin sponge which are commercially available were found to be too narrow and too thin for the purposes of this experiment. The dry compressed sheet of gelatin sponge was then wrapped about the wound in the vessel and held in place with several sutures of extra chromic surgical gut (size 0). The bulldog clamps were then released and the blood flow restored without further hemorrhage (fig. 2 *A*).

The technic described was used in the first five experiments. The gelatin sponge was not found to be strong enough to withstand alone the arterial blood pressure. The technic was then modified by wrapping the gelatin sponge "cuff" in a sheath of chromic surgical gut. This sheath was held in place by several sutures of extra chromic surgical gut (fig. 2 *B*). Some care was necessary in tying up the sutures to avoid constricting the lumen of the vessel and thus impairing the blood

11. Jenkins, H. P., and Clarke, J.: Gelatin Sponge: A New Hemostatic Substance; Studies on Absorbability, Arch. Surg. **51**:253 (Nov.-Dec.) 1945. Jenkins, H. P.; Janda, R., and Clarke, R.: Clinical and Experimental Observations on the Use of Gelatin Sponge or Foam, Surgery **20**:124, 1946.

12. Jenkins, H. P.; Senz, E. H.; Owen, H. W., and Jampolis, R. W.: The Present Status of Gelatin Sponge for Control of Hemorrhage, with Experimental Data on Its Use for Wounds of the Great Vessels and the Heart, J.A.M.A. **132**:614 (Nov. 16) 1946.

flow. The subsequent sixteen experiments were then performed by supplementing the gelatin sponge "cuff" by a sheath of chromic surgical gut, except for one experiment, in which a plain surgical gut sheath was used but found to be inadequate for the purpose.

The chromic surgical gut sheath was prepared by two manufacturers [13] of surgical gut by wrapping the flat strips of sheep intestine, such as are used for

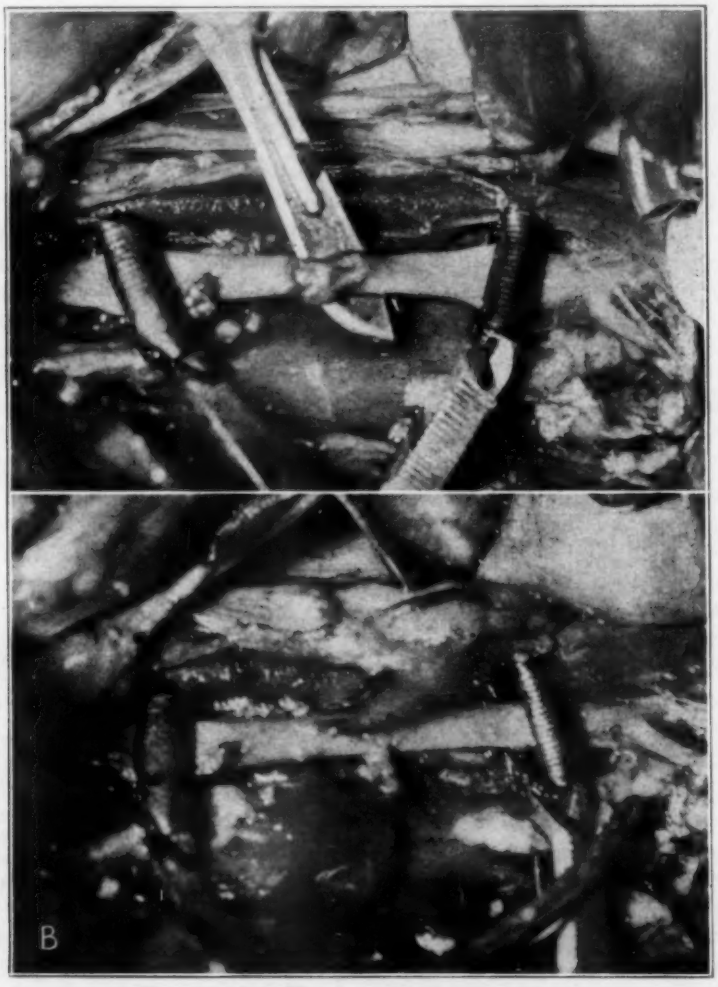

Fig. 1.—*A*, scalpel wound of aorta of dog; *B*, hemorrhage from wound of aorta.

making ligatures and sutures, about a rod. The rod was removed after the strips had dried, thus forming the sheath. It was necessary to split the sheath along one side so that it could be wrapped about the gelatin sponge cuff. A size was selected which permitted some overlapping of the sheath when the sutures were tied up. The

13. Ethicon Suture Laboratories, and Armour Laboratories.

chromicizing process was carried out prior to wrapping on the rod by the method customary for the manufacturer. Adequate sterilization for the purposes of these experiments was obtained by immersing in 95 per cent ethyl alcohol for several days. The manufacturers are working out a method of providing this sheath in sealed glass tubes after their usual process of heat sterilization such as is used for ordinary surgical gut.

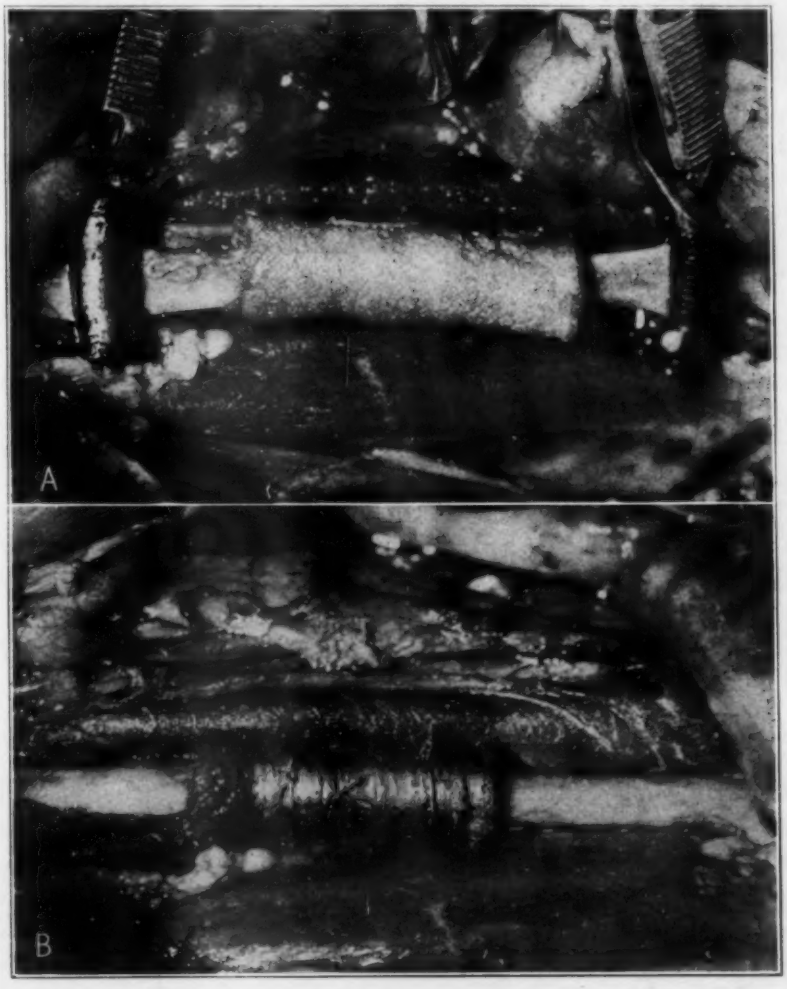

Fig. 2.—*A*, gelatin sponge "cuff" wrapped about wound of aorta while hemorrhage is controlled temporarily by bulldog clamps; *B*, chromic surgical gut sheath which surrounds gelatin sponge "cuff." The sheath is held in place with several surgical gut sutures. The blood flow is restored and the hemorrhage controlled.

At autopsy, the vessel was carefully dissected out and removed. Photographs were taken before and after opening the lumen of the vessel. The specimens were preserved in formaldehyde solution (10 per cent of the U.S.P. concentration), and sections were cut through the wound in the vessel for microscopic study.

RESULTS

All the 22 animals survived the immediate postoperative period. In the series of 5 animals in which the gelatin sponge "cuff" alone was used to control hemorrhage from a wound of the aorta a blowout occurred in 2, which caused death on the fourth and the sixth day respectively from massive retroperitoneal hemorrhage. The other animals in this series died on the second, third and sixth days after operation from distemper and pneumonia. There was no evidence of secondary hemorrhage in these animals, and the lumen of the vessel was found to be patent. However, the gelatin sponge cuff was rather badly fragmented, especially where the sponge was held by the sutures. In one experiment in which the plain surgical gut sheath was used a blowout occurred on the fourteenth day which produced a fatal hemorrhage. In addition, there was a mural thrombus in the region of the wound in the vessel.

In the series of 16 animals in which the gelatin sponge "cuff" was supported by a sheath of chromic surgical gut there was only one blowout from the arterial wound. This occurred on the fourth day. In a second experiment, there was a blowout on the seventeenth day which occurred proximal to the through and through stab wound of the aorta. The wounds in the vessel wall were healed; however, there appeared to be erosion of the vessel where the chromic sheath cut into it at the level of the most proximal chromic surgical gut suture, which was apparently tied up too tight. Six animals died from distemper and pneumonia, or were killed, on the third, the sixth, the ninth, the tenth, the eleventh and the fourteenth day. The sponge "cuff" and sheath were found to be intact, and the lumen of the vessel was patent and free from evidence of thrombosis. The wound of the vessel was easily identified.

Eight animals which survived for longer periods were killed as follows: 2 on the twenty-fourth day and 1 each on the fortieth, the forty-eighth, the fifty-fourth, the sixty-fourth, the seventy-third and the eighty-eighth day. The chromic surgical gut sheath was found to be encapsulated in fibrous tissue which gave additional support to the vessel wall (fig. 3 *A*). When this fibrous capsule was opened up, the chromic sheath could be readily identified up to about six weeks (fig. 3 *B*). After six weeks to two months, it was difficult to identify the chromic sheath as a separate layer, as it was in a moderately advanced stage of absorption and incorporated in the tissues surrounding the vessel wall, imparting a brown or green color to these tissues (fig. 3 *C*). The gelatin sponge could usually be identified grossly in the animals which survived three to six weeks when the vessel was

cut open. The location of the wound in the vessel wall could be detected as a white scar which was apparently well healed over (fig. 4 *A*). In one instance, however, a large propagating thrombus was adherent to the wound in the vessel wall. This thrombus pro-

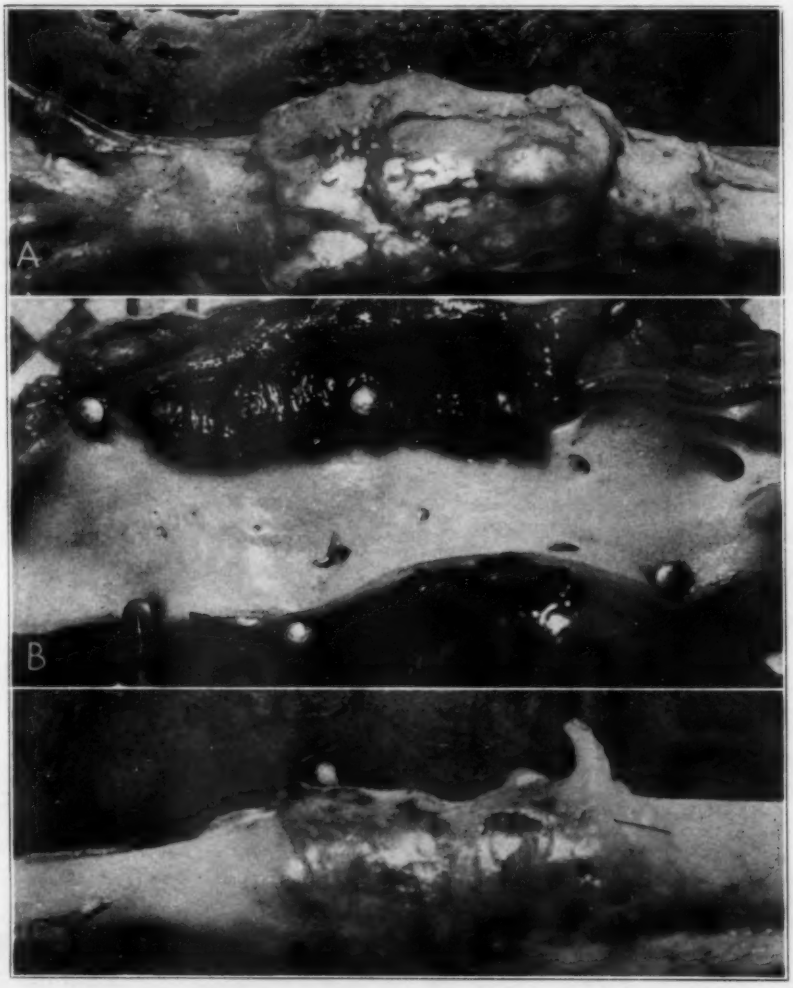

Fig. 3.—*A*, a specimen of the aorta twenty-four days after scalpel wound and control of hemorrhage by gelatin sponge "cuff" supported by chromic surgical gut sheath. The sheath has become encapsulated in fibrous tissue which is continuous with the vessel wall, thus providing additional support. *B*, a specimen of the aorta twenty-four days after scalpel wound in vessel wall. The chromic surgical gut sheath can be seen under the partially removed overlying fibrous capsule. The wound can be identified as a small depression adjacent to the lumen of a small branch of the aorta. *C*, a specimen of the aorta forty days after repair of scalpel wound by gelatin sponge "cuff" supported by chromic surgical gut sheath. The sheath has undergone moderate absorption and is incorporated in the fibrous tissue surrounding the aorta at this point. There is a dark color imparted to the tissues by the remnants of sheath.

truded into the lumen but did not occlude it (fig. 4 *B*). There was evidence of aneurysmal dilatation of the vessel wall at the site of injury in one of these specimens. There was induration of the tissues about the sheath in several instances which was not easily explained.

The microscopic studies revealed healing of the wound in the wall of the vessel by scar formation which was covered by a newly formed intima (fig. 5). The chromic surgical gut sheath was found to be present in varying stages of absorption. There was a moderate cellular reaction to the surgical gut which varied in intensity in the various sections studied.

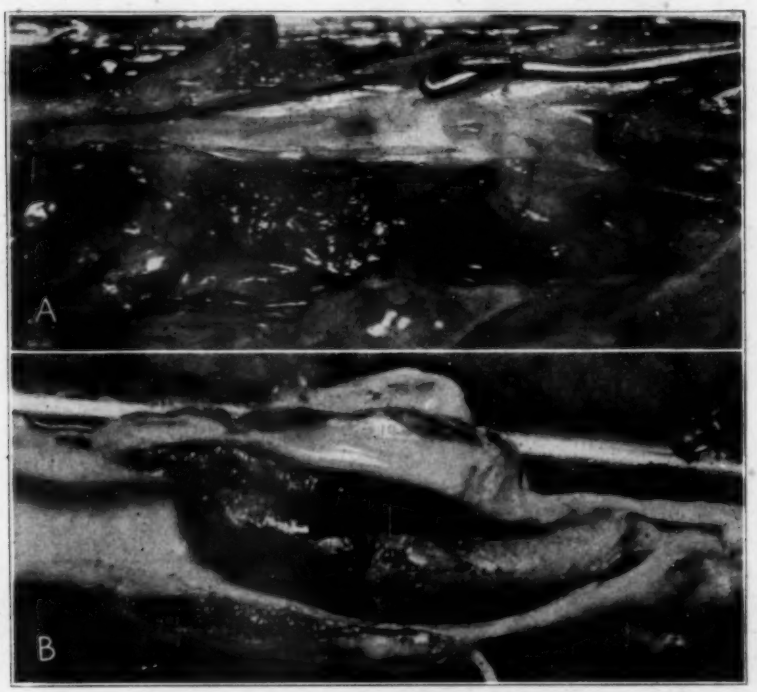

Fig. 4.—*A*, a specimen of the aorta seventy-three days after scalpel wound and repair with gelatin sponge "cuff" and chromic surgical gut sheath. The healed wound can be identified near the end of the metal pointer. *B*, a propagating thrombus adherent to the wall of aorta where scalpel wound was produced forty days previously. Repair of wound by "cuff" and sheath. The thrombus did not occlude lumen completely.

The gelatin sponge was generally found to be in a more advanced stage of absorption than the surgical gut sheath. The chromic gut sheath of one manufacturer was somewhat less chromicized than that of a second manufacturer which prepared an especially heavily chromicized sheath. The rate and mode of absorption in the tissues of these two types of chromicized material were practically the same as those described in studies on the absorption of surgical gut; i. e., intermediate absorption

Fig. 5.—A photomicrograph of a healed wound in the wall of the aorta after twenty-four days. The fibrous scar has filled in the defect in the media and adventitia and has been covered by an endothelial surface which merges with the intima. Beneath the wound there is evidence of gelatin sponge in a moderate stage of absorption and replacement by fibrous tissue. Under this can be seen remnants of the chromic catgut sheath which is undergoing absorption principally by the action of macrophages.

and slow absorption.[14] It was our impression that the more heavily chromicized material produced less tissue reaction during the relatively longer period of absorption than the other material.

COMMENT

A significant point in this work is that arterial hemorrhage of a magnitude which would cause rapid exsanguination and death within a few minutes in experimental animals can be controlled by an absorbable hemostatic agent without resorting to ligation or arterial suture. Granted that the hemostatic agent used was not sufficiently strong to withstand alone the arterial pressure after several days in the tissues, nevertheless the principle of control of arterial hemorrhage by an absorbable spongy material is of importance. Owing to the friability of the sponge, it was found necessary to give additional support by a sheath of chromic surgical gut to prevent blowouts during the healing of the arterial wound. The force of the arterial blood pressure was obviously too great for the physical structure of the sponge. A contributing factor was the cutting effect of the sutures on the sponge which was produced by the arterial pulsations. This sometimes resulted in cutting the gelatin sponge into several segments. It is possible that this cutting effect may be prevented by using a tougher and stronger spongy material. However, the chromic surgical gut sheath appeared adequate to hold the sponge in place and give it sufficient support during the period of healing of the arterial wound. The sheaths which were not chromicized became so soft after a few days in the tissues that they were found to be unsuitable for this type of work. The chromic surgical gut sheath represents an innovation in absorbable materials which may find uses in other fields of surgery and deserves further study.

Smith has used the cuff technic in experimental arterial anastomoses in which only seven interrupted sutures were used to bring the ends of the artery into apposition. His experiences with different types of cuffs such as jugular vein segments, rubber, fascia, muscle and oxidized cellulose were unsatisfactory, as thromboses developed. When concentrated fibrinogen solution was used to prepare a mold about the site of the anastomosis producing a fibrin layer it was found that this would not withstand the arterial pressure.

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14. Jenkins, H. P., and Hrdina, L. S.: Absorption of Surgical Gut (Catgut): I. The Decline in Tensile Strength in the Tissues, Arch. Surg. **44**:881 (May) 1942); II. Pepsin Digestion Tests for the Evaluation of Duration of Tensile Strength in the Tissues, ibid. **44**:984 (June) 1942. Jenkins, H. P.; Hrdina, L. S.; Owens, F. M., Jr., and Swisher, F. M.: III. Duration in the Tissues after Loss of Tensile Strength, ibid. **45**:74 (July) 1942. Jenkins, H. P.: IV. Recommendations for Absorbability and Digestibility Specifications. ibid. **45**:323 (Aug.) 1942.

The blowout which occurred from the eroding effect of the chromic surgical gut sheath where it was held by the most proximal suture is of interest and demonstrates a potential hazard of this method. Murray [15] has found that "rigid bands applied around the site of repair of vessels may be a menace in causing necrosis of the vessel wall." The chromic sheath usually becomes softened in the tissues after one or two weeks and should not present the same menace as a metal band. Nevertheless, this observation is significant and must be considered as a limitation to the method described, and illustrates the need for care in tying the sutures with just enough tension to make snug apposition of the sheath about the sponge without producing constriction of the vessel. Furthermore, it suggests that it would be wise to allow an excess of gelatin sponge to extend beyond the sheath to act as a buffering pad and thus protect the artery from erosion at the proximal end of the sheath. This would probably be desirable also at the distal end of the sheath.

There is no question about the desirability of utilizing a careful arterial suture for repair of wounds or for arterial anastomoses. The cuff technic such as was utilized in these animals merely offers an experimental method which might have some clinical application in circumstances in which a satisfactory repair is not feasible by the standard suture technic. It is probable that its most potential field of usefulness would be as an additional safeguard against blowout of an arterial suture line. There is no place in surgery where greater care must be exercised in placing every single suture and obtaining the optimum apposition with the minimum of strangulation of tissue. The outcome is so dependent on getting every suture correctly placed that only perfection in technic permits success in this type of surgery.

In traumatic lacerations of arteries, Pratt [16] has found it desirable to reenforce the silk suture line with a strip of fascia or muscle wrapped about the site of repair. This suggests a need for some type of reenforcement which could be supplied by the method described here.

In arteriotomy for removal of an embolus, one may encounter some technical difficulty in obtaining a satisfactory closure with sutures if there is much arteriosclerotic change. Furthermore, the healing of the vessel may be impaired by the presence of arteriosclerosis. The gelatin sponge cuff and chromic surgical gut sheath may be found to be especially appropriate under such circumstances as a reenforcement of the suture line as suggested by de Takats.[17]

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15. Murray, G.: The Healing of Arteries and the Relationship to Secondary Hemorrhage, Surgery **18**:624, 1945.

16. Pratt, G. H.: The Surgical Management of Acute Arterial Occlusion, J.A.M.A. **130**:827 (March 30) 1946.

17. de Takats, G.: Personal communication to the author.

It is possible that with the aid of the new absorbable hemostatic agents some modifications of the standard suture technic of vascular repair may be developed. In the repair of a wound of an artery or in an arterial anastomosis, the suture technic must perform two functions: It must bring the vessel walls into apposition and produce a "watertight" closure. It may be found feasible with these new hemostatic agents to depend on the sutures mainly for good apposition of the vessel wall and rely on the cuff of hemostatic agent to maintain a "watertight" repair of the wound or line of anastomosis. This may make it possible to obtain satisfactory arterial repair after a less careful suture technic than that now required.

One of the principal hazards of any type of blood vessel repair or anastomosis is the problem of thrombosis such as was observed in one experiment. In arterial suture, the development of a thrombus may be a relatively slow process which may require several weeks or more before the thrombus occludes the vessel. Meanwhile collateral circulation has had an opportunity to develop, so that in the event of complete occlusion by the thrombus the danger of peripheral ischemia and gangrene is substantially lessened. However, with the advent of the anticoagulants for use in the treatment of thrombotic vascular disease another hazard of vascular surgery may be minimized, as pointed out by Murray.[18] A refinement in the anticoagulant therapy which deserves mention is the use of heparin in the Pitkin menstruum, such as was employed by Loewe, Rosenblatt and Hirsch for venous thromboembolic disease.[19]

If the gelatin sponge cuff and chromic catgut sheath should prove of value in minimizing blowouts, and with the aid of anticoagulants to prevent thromboses, it should be possible for more well trained surgeons to include in their repertory the surgery of the vascular system, which has thus far been a highly specialized field in which only a few have become proficient.

SUMMARY

An experimental nonsuture method for repair of wounds of arteries has been presented which consists of wrapping a cuff of gelatin sponge about the wound in the vessel and supporting this with a sheath of chromic surgical gut. With this method it has been possible to control hemorrhage, restore the flow of blood and prevent for the most part subsequent blowouts.

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18. Murray, G. D. W.: Heparin in Surgical Treatment of Blood Vessels, Arch. Surg. **40**:307 (Feb.) 1940.

19. Loewe, L.; Rosenblatt, P., and Hirsch, E.: Venous Thromboembolic Disease, J.A.M.A. **130**:386 (Feb. 16) 1946.

CONCLUSIONS

The gelatin sponge cuff and chromic surgical gut sheath offer a new experimental method which may be found on further study to have a clinical application such as in the emergency treatment of wounds of major arteries, where one may not be in a position to do a careful arterial suture, and as a "secondary line of defense" against blowouts where arterial suture has been performed for a wound of the vessel or for anastomosis.

The chromic surgical gut sheath is an innovation in absorable materials which may find uses in other fields of surgery.

NOTE.—Subsequent observations on the heat-sterilized type of heavily chromicized sheath suggest that six months or more may be required before absorption occurs.

ORTHOPEDIC OPERATIVE PROCEDURES ALLOWING EARLY MOTION

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NEW YORK

TO ACHIEVE early motion is one of the main objectives in modern treatment of orthopedic problems. The method of simply immobilizing an injured member in plaster for a prolonged period is being replaced by various operative procedures which allow early motion and which are designed to accomplish the dual purpose of producing a satisfactory end result and at the same time preserving tone and function of the surrounding soft tissues.

SURGICAL PROCEDURES

The following examples of surgical procedures are submitted as designed to accomplish these ends. The illustrations and the cases referred to are taken from various series at the Presbyterian Hospital and the New York Orthopaedic Hospital in New York city.

Clavicle.—Injuries causing ruptures of the conoid and trapezoid ligaments produce complete coracoclavicular and acromioclavicular separations, as shown in figure 1*A*. Various types of treatment have been proposed for this kind of injury, ranging from prolonged immobilization in plaster to repair of the coracoclavicular ligaments by use of fascia or other retention sutures. These required long periods of immobilization. It seems that by far the best results are achieved when a Kirschner wire is drilled across the acromion into the distal clavicle, as in figure 1 *B*. Usually the ruptured ligaments then heal spontaneously, and not infrequently calcification can be seen in the conoid and trapezoid ligaments, indicating a healing of this area of injury. The shoulder and arm are permitted to be used; no plaster is applied and no immobilization required. Thus, complete motion and maintenance of muscular tone are accomplished.

Elbow.—In fractures of the radial head in which there is displacement into the brachialis anticus muscle (fig. 2*A*) immediate operation is indicated. An incision on the anterior aspect of the elbow should be

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb. 22, 1947.

made to evacuate the hematoma. This is a most important step in the prevention of myositis ossificans. The radial head is removed, as shown in figure 2*B*. Postoperatively, the elbow is put in a sling, and motion within pain limits is permitted within the first twenty-four hours. The patient should never receive massage or manipulation of the involved area. Prior to the use of this procedure, myositis ossificans developed in approximately 10 per cent of the cases, but since its adoption this most common complication has not developed in any case.

Fig. 1.—Injury of the clavicle. *A*, roentgenogram showing coracoclavicular and acromioclavicular separations; *B*, Kirschner wire drilled across the acromion into the distal clavicle.

Hand.—In cases of fractures of the metacarpal bones, shown in figure 3*A*, it has been found extremely advantageous to insert Kirschner wires both above and below the fracture, as indicated in figure 3*B*. This can be done under local anesthesia. The wires should be cut close to the bone and the skin allowed to close over the ends of the wire. Postoperatively, no plaster is applied and early motion of the

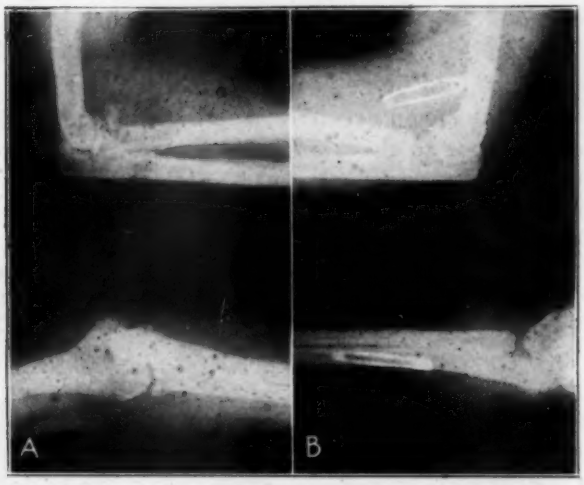

Fig. 2.—Fracture of the elbow. *A*, displacement of the radial head into the brachialis anticus muscle; *B*, radial head removed.

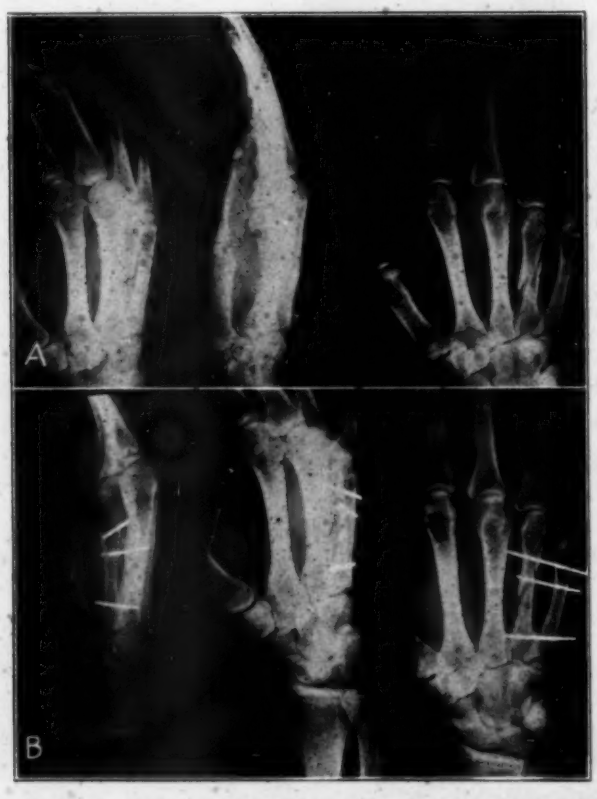

Fig. 3.—*A*, fracture of the metacarpal bones. *B*, Kirschner wires inserted.

hand is encouraged. The patient is generally allowed to resume his duties immediately. The wires are usually removed two months post-operatively. The roentgenograms show a fracture suffered by a neuro-surgeon, who resumed operating thirty-six hours after injury. This method of immobilization and active use is applicable in fractures of all the metacarpal bones except the first.

Hip.—One of the most difficult problems to treat properly is that of the elderly patient who suffers an intertrochanteric fracture. Although

Fig. 4.—Reduction and immobilization of an intertrochanteric fracture of the hip

it is known that these fractures heal rapidly and exceptionally well, it is difficult to immobilize them sufficiently to allow the patient to be ambulatory and thus prevent the common complications of decubiti or pulmonary stasis. It therefore is advantageous to insert a Smith-Petersen nail and then apply a McLaughlin plate, which is so fashioned that one can adjust for valgus or varus of the hip. In this way firm immobilization is accomplished, which permits the patient to be out of bed the following day. Thus at no time is it necessary to put the

patient in traction, suspension or plaster. It is felt that this method of fixation is advantageous in that it is adjustable for varus and valgus deformities. Previous to the use of this procedure intertrochanteric fractures presented much more of a problem than the transcervical fractures of the neck of the femur because of the difficulty in acquiring satisfactory immobilization without the use of plaster. Figure 4 shows the reduction and immobilization of such a fracture by this method.

Fig. 5.—Roentgenogram taken six weeks after the insertion of the Kunschner nail for a fracture of the femoral shaft.

Femur.—Recently the method used in treating fractures of the femoral shaft is the one popularized by the Germans during the last war. The use of a Kunschner nail inserted through the greater trochanter, down the medullary cavity and across the fracture line and well embedded into the distal fragment has given satisfactory immobilization and allowed early ambulation. Figure 5 is a roentgenogram of such a fracture made

six weeks after the insertion of the Kunschner nail. The patient was permitted to walk with crutches two weeks after operation. The crutches were discarded seven months postoperatively, at which time solid union of the bone was present.

Tibia.—It is well known that union is slow in fractures of the tibia, and often in the accomplishment of union considerable stiffening of the joints above and below the fracture is encountered. Therefore, early internal fixation by plate and screws and the use of a transfixion screw are often indicated. Figure 6 shows the postoperative roentgeno-

Fig. 6.—Postoperative roentgenogram of a fractured tibia treated with internal fixation by plate and screws.

gram of a fractured tibia treated in this manner. The extremity is then suspended in a Thomas splint and a Pierson attachment, and at no time is plaster applied. The joints of the knee and ankle are mobilized immediately, and the patient is allowed to be ambulatory as soon as the sutures are removed.

Ankle.—It is well known that one of the most difficult injuries to treat is a fracture of the ankle which extends into the joint, with a

separation of the inferior tibiofibular ligamentous structure (fig. 7 *A*). The end result is rarely good unless the fractures are accurately reduced and firmly immobilized as in figure 7 *B*. Open reductions accomplish these two necessary objectives.

Fig. 7.—Roentgenogram of a fractured ankle. *A*, separation of the inferior tibiofibular ligamentous structure; *B*, reduction and immobilization.

Early motion is instituted, and plaster is never applied. By this method motion of the joints is maintained, soft parts do not become brawny and indurated and normal bony contour is restored.

Achilles Tendon.—In treatment of ruptures of the achilles tendon the method advocated by McLaughlin has been employed, which utilizes the principle of the Bunnell pull-out suture whereby the tendon is allowed

to heal end to end without the tension on the suture line produced by contraction of the gastrocnemius muscle. As illustrated in figure 8, the frayed ends of the achilles tendon are freshened (*A, 1*). A drill hole is made from the lateral to the medial side of the os calcis (*A, 2*) and a stab wound made on the medial aspect of the os calcis (*A, 3*). A wire tension suture is then placed through the proximal end of the severed achilles tendon. Through the hole in the os calcis a stainless steel bolt is passed (fig. 8 *B, 3*). The wire previously placed through the proximal portion of the tendon is then tightened around the bolt (*B, 2* and *3*). The approximated ends of the tendon are then sutured with black silk. This permits easy identification and withdrawal of the wire at a later date. The protruding end of the bolt is then cut flush with the os calcis and the entire area closed. In this manner there are no protruding bolts or wires through the skin.

After operation, the lower part of the leg is encased in an Unna paste boot and a three-quarter inch (2 cm.) raise of heel given. The patient

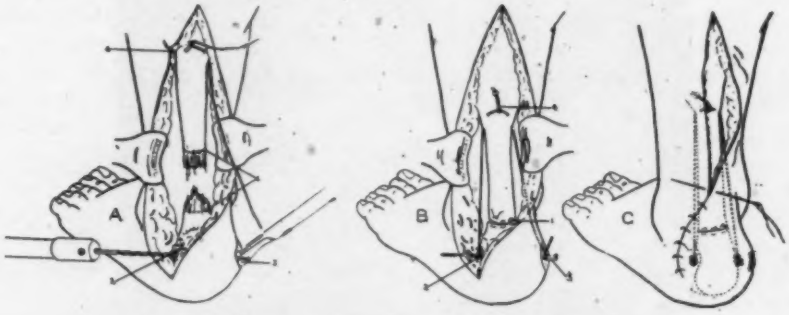

Fig. 8.—Treatment of rupture of the Achilles tendon.

is allowed to walk about two weeks after operation. The wire and bolt are removed between three and six weeks postoperatively. This same principle is used in ruptures of the patellar tendon.

Spine.—The time-honored method of spine fusion—that of immobilization in plaster for six to twelve weeks—has undergone revolutionary changes within the past two years. The Hibbs type of fusion is performed in the regular manner, but in addition, according to the method advocated by Von Lackum, a bone chip is inserted into the facet space and a hole drilled from the lamina through the facet into the lateral mass of the sacrum. Into this hole a stainless steel screw is inserted (fig. 9). A one and a quarter inch (3 cm.) screw is used in fusions of the fifth lumbar and first sacral vertebrae and a 1 inch (2.5 cm.) screw in joints above this level. The fusion is usually reenforced by bone from the wing of the ilium. At times, however, bank bone is used, which is

bone of a homogenous nature that has been preserved by freezing and stored for use when required.

In fusions of the fifth lumbar and first sacral vertebrae the patient is out of bed on the twelfth postoperative day and allowed home wearing a Knight spinal brace on the fifteenth to twentieth postoperative day. In fusions of the fourth and fifth lumbar and first sacral vertebrae the patient is kept in bed for six weeks and then allowed to be ambulatory, again with the use of a Knight spinal brace.

It might be felt that too much operative work is advocated in this paper. However, I would like to point out that isolated instances have been chosen for the material on which this report is based. Also, it is of interest to know that at the Presbyterian and New York Orthopaedic hospitals open reduction is carried out in only 10 per cent of

Fig. 9.—Spine fusion in which screws have been used.

all the fractures treated. It is true that in most other hospitals open reduction is performed in only 3 per cent, but nonetheless it is felt that the handling of such fractures as are mentioned herein in the manner described affords the best results.

DISCUSSION

Dr. George J. Curry, Flint, Mich.: I should like to discuss the paper of Dr. Stinchfield. I strongly support the basic principles which he has emphasized for the management of certain fractures, urging the selection of any type of management that will permit early ambulation. The six examples that he has presented are well chosen and clearly show the value of early internal fixation.

I should like to comment especially on fractures in and about the hip joint. He made the statement that with the selection of internal fixation the patient with a fractured hip may become ambulatory early and be permitted sometimes to sit up the first hour or the first day. This is more applicable to fractures of the

femoral neck and certain fractures in the trochanteric area. During the past nine years at Hurley Hospital, Flint, Mich., we have operated for and internally fixed fractures in the hip region in 284 cases. My personal experience with intertrochanteric fractures of various types includes 89 cases in which internal fixation was carried out.

Roentgenograms frequently do not show the degree of comminution found at the time of operation. I feel that a note of caution should be given concerning cases with much comminution in relation to permitting ambulation in a wheel chair from the first postoperative day. It is obvious that the operation may be disturbed by the mechanical procedures necessary to accomplish this act. Considerable ambulation can be accomplished with the patient in bed by the use of the back rest and the frequent movement of unaffected extremities. I have seen patients who I thought were physiologically inert sitting in a wheel chair. Certainly the patient weighing 225 pounds who has an intertrochanteric fracture that has been internally fixed is a more difficult problem than the slender, smaller type. Patients with simple intertrochanteric fractures without comminution may enjoy all the phases of early ambulation.

There are intertrochanteric fractures of the complex type in which the comminution is so marked that one would not select any type of internal fixation because of the failure to find an area in which the internal fixation agent would hold. I believe that this type of fracture should have skeletal traction.

DR. PAUL GREELEY, Chicago: One thing I should like to ask Dr. Stinchfield is about the used of banked bone. There is a large group who believe that the use of such bone grafts is open to question because of absorption. I should like to know what the ultimate clinical and microscopic results are.

DR. FRANK E. STINCHFIELD: The question of "bone bank" is one of extreme interest to me. The bone bank was first established about a year ago at New York Orthopaedic Hospital for the purpose of supplying extra bone when needed in various surgical procedures. It is most appreciated in spine fusions, arthrodeses and scolioses.

The use of autogenous bone seems to be more satisfactory than the use of homogenous bone. I do not advocate the use of homogenous bone in place of autogenous bone but do advocate its use when autogenous bone is not available.

Actually, few of the bone cells survive. However, we have seen some of the cancellous bone cells survive but few, if any, of the cortical cells. The chief advantage of bank bone is that the bone affords a local source of calcium and acts as a trellis for new bone formation.

INTEROSSEOUS WIRING IN THE TREATMENT OF FRACTURES OF THE MANDIBLE

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TORONTO, CANADA

INTEROSSEOUS wiring as a method of treatment in suitable fractures of the mandible has not been used as extensively as, in my opinion, its value justifies. Its use in the past has indeed been discouraged because of the complications that may follow. It is proposed to discuss, in this communication, the use of the method in the treatment of forty-eight fractures in 46 patients. Eighteen of these patients were soldiers injured by enemy action.

Wire suture of the fractured mandible is applicable in fractures of the edentulous mandible, fractures having an edentulous posterior frag-

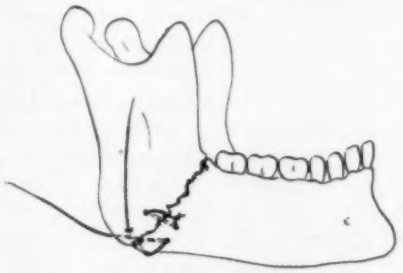

Fig. 1.—The method of fixation is shown; i. e., simple suture above and figure 8 suture below.

ment, multiple fractures (for stabilization of the main fracture), bilateral fracture through the mental foramina with downward displacement of the central fragment, gun (or shell) wounds (for stabilization when a portion is missing) and in fractures at the base of the condyle with displacement.

Incision is made below the mandibular line. No attempt is made to protect the inframandibular branch of the facial nerve, as recovery

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb. 21, 1947.

From the Division of Plastic Surgery, Toronto General Hospital, and the Division of Plastic Surgery, Christie Street Hospital, Department of Veterans' Affairs, Toronto. The illustrations are from the Medical Arts Department, Christie Street Hospital.

uniformly has followed its injury. The fracture ends are freed of soft tissue on both surfaces for about ¾ inch (1.9 cm.). Two holes are drilled in each end as in figure 1. A high speed drill should not be used. Twenty-six gage stainless steel wire is threaded through the upper two holes as a simple suture. It is not tightened until the other wire is in

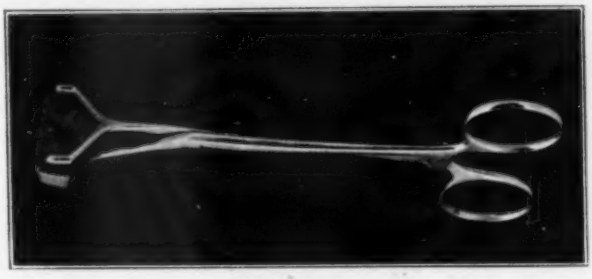

Fig. 2.—A special instrument for holding the reduced fracture in position is illustrated. The pan is placed on the lingual side. Injury to deeper structures while drilling is prevented, and threading the wire through the drill holes is made easier. It was made for me by Messrs. Chas. F. Thackray Ltd., 252 Regent Street, London W1, England.

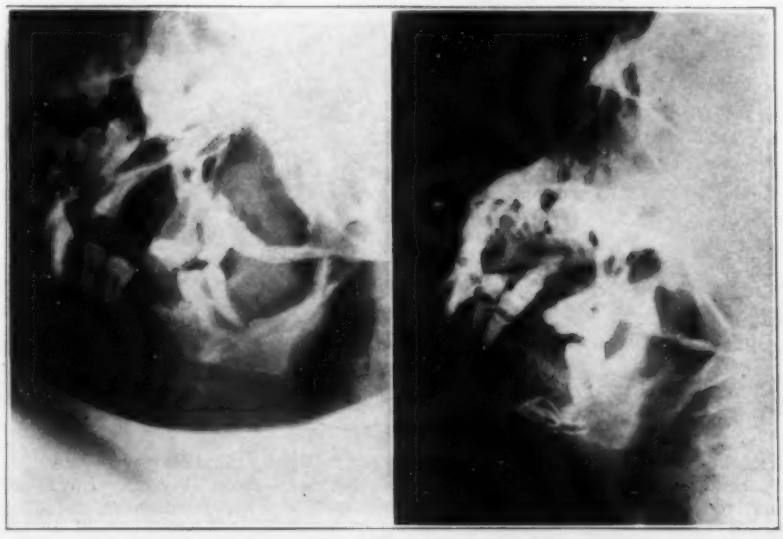

Fig. 3.—A fracture in the molar region is demonstrated. Displacement is typical. Extrusion of the second molar is present. Position following extraction of the molar, reduction of the fracture and fixation by interosseous wiring is shown at the right.

place. It was found that some degree of displacement of the posterior fragment recurred if the lower wire was also used as a simple suture. At the suggestion of Lieut. Colonel G. Franklin, C.D.C., this wire was

placed as a figure 8, with the crossed portion under the edge of the fragment not tending to become displaced. This prevented any shift postoperatively and has become a routine practice. The wires are tightened with the fracture reduced.

Sulfanilamide or sulfathiazole powder was dusted into the wound in 25 patients. Penicillin was given postoperatively to 24 patients. Closure was done in layers without drainage.

As it is believed that the least possible movement at a fracture line, particularly when foreign material is present, aids the development of

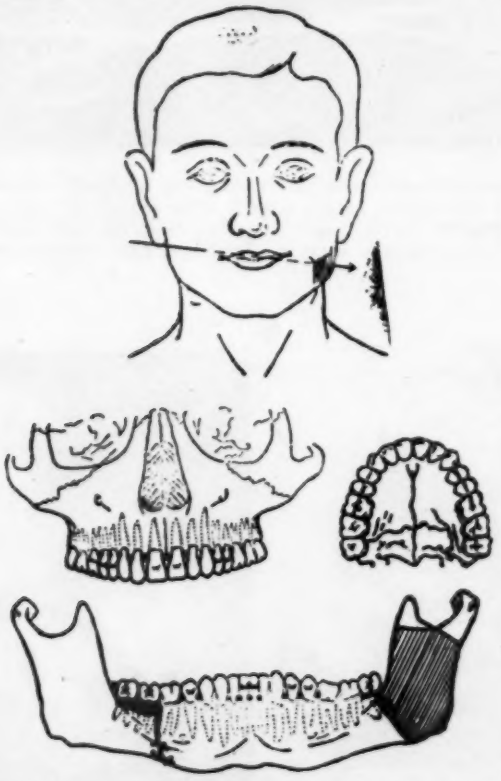

Fig. 4.—The result of a gunshot wound suffered July 20, 1944 is indicated. The left ascending ramus was missing. Operation was done July 25. Interosseous wiring, plus intraoral wiring, was used to maintain the position of the central fragment.

solid union with a minimum of complication, intraoral fixation was used as well in 43 patients, pins and a Gunning splint in 1 patient each, and no secondary fixation was used in the forty-sixth patient. While not necessary, the instrument illustrated in figure 2 is of value in placing the holes and the wire. The fracture is reduced. The pan is placed on the lingual side of the fracture, the two arms on the buccal. Locking

the handles holds the fracture in position, allows the holes to be drilled without fear of injury to deeper structures and, since the floor of the pan slopes away from the mandible from above down, the wire ends present in the wound after passing through the drill holes.

If a tooth in the line of fracture was rather loose or fractured, or had a denuded root in the fracture line, it was extracted before the incision was made. If possible, an intraoral dental roentgenogram should be taken, since the information obtained from it is of more value than that obtained from the ordinary large roentgenogram. Extraction was done in 17 instances. In 10 of these 17 cases a postoperative complication developed, an infection in 9 cases and delayed union in 1.

TABLE 1.—*Number of Patients and Fractures and Types of Fractures*

Number of patients	46
Number of fractures	48
Number of angle fractures	21
Number of body fractures	7
Number of condyle fractures	2
Number of war injuries	18

TABLE 2.—*Complications*

Osteomyelitis	1
Infection of soft tissue	
Severe	1
Mild	8
Delayed union	4
Nonunion	3
Sinus due to wire	2

The method has been used in 13 cases having an edentulous posterior fragment; in 12 of these the fracture was at the angle, and in 1 it was in the mental region. No fractures in edentulous patients are included in this study. Thirteen patients had multiple mandibular fractures; in 7 of these an angle fracture was wired; in 5 a fracture at or just back of the mental foramen was wired, and in 1 both angle fractures were wired. One instance of bilateral wiring in a case of fracture through the mental foramina is included in the series. As already stated, 18 cases were the result of war injury, the fractures being compound and either comminuted or multiple. In 2 cases condylar fractures with displacement were wired.

Six of the forty-eight fractures were simple. Postoperative infection did not develop in any of these. There were ten postoperative infections in the remaining forty-two compound fractures wired. Two of these were serious, in one case resulting in osteomyelitis with sequestration, and in nonunion in the other. One of the other eight infections produced

Fig. 5.—The position of the wires in the patient referred to in figure 4 is shown as of December 1946. The left ascending ramus has been replaced by bone graft.

Fig. 6.—A compound fracture of the right ascending ramus is shown. Marked displacement of the lateral orbital rim can be seen. The patient was hit over the right malar bone by the bolt of a rifle after firing. Operation was done eight hours after injury. The postoperative picture, at the right, shows the position obtained.

an abscess involving soft tissue only which had to be drained but caused no further damage. The remaining seven were minor infections of the soft tissue in or near the region of the fracture.

The wires were eventually removed in 5 cases. Two were in the cases of serious infection and two were removed because of a persistent sinus leading down to the wire which promptly healed after removal of the wire. One set of wires, present in the symphysis region, was removed months later at the time of doing a buccal inlay graft (original injury due to a machine gun bullet).

Nonunion occurred in 3 cases, 2 already mentioned and the third for no obvious reason.

There was 1 death in this series. The patient, a soldier, had multiple injuries and died of uremia on the eleventh day after injury. No complication was present at the site of operation.

Union occurred in the cases without infection in an average of forty-four days. In cases with infection union occurred in an average of fifty-four days. The patient in whom osteomyelitis developed should not

TABLE 3.—*Results*

Death	1
Solid union	44
Bone graft	3

have been operated on, and today would not be so treated. He was treated five days after injury. His face was markedly swollen and his mouth dirty. A third molar had to be extracted prior to operation.

In the 2 cases of condylar fracture wiring was done in order to reduce the fracture and to maintain the position. This fracture is one of the rare fractures, if not the only fracture, in the body in which little or no attempt is made to regain anatomic alinement. One of the open reductions proved rather simple technically, the other very difficult. In both cases wiring was done through a submandibular incision. It was felt that the functional result obtained was no better than that resulting from the usual methods of treatment, so open reductions were abandoned. While it is true that the immediate result was no better, it is impossible to say what the comparable result was years later. A study of the late results of fractures of the mandibular condylar process is an important contribution that has not as yet, to my knowledge, been made.

Four cases of delayed union and 3 of nonunion occurred in this series. All 3 nonunions were successfully treated by bone grafting, cancellous chips being used. Thus, of the forty-eight fractures treated, forty-four united satisfactorily.

The use of interosseous wiring in the treatment of fractures of the mandible is of value in maintaining edentulous fragments in anatomic position; in stabilizing a mandible when a portion is missing or when multiple fractures are present; in maintaining accurate reduction of the central fragment when fractures are present in both mental regions,

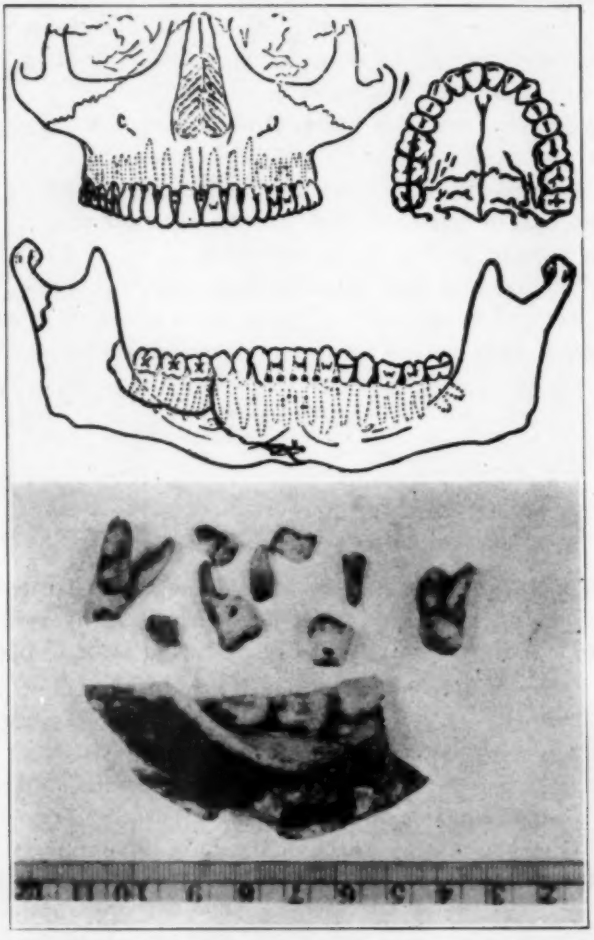

Fig. 7.—The injury illustrated was suffered by a tank officer who was found unconscious lying part way out of the turret after night maneuvers just before D day. It was believed that he had been hit by a telephone guy wire. Interosseous wiring maintained the position of the right fragment. Operation was done six days after injury. The teeth and bone removed are shown.

and is of questionable value in the treatment of fractures of the condylar process. Interosseous wiring insures obtaining and maintaining a more accurate reduction of the fracture than any other applicable method of

therapy. The method should never be used when acute infection is present. Its use is not contraindicated in compound fractures free of clinical signs and symptoms of infection.

DISCUSSION

DR. PAUL GREELEY, Chicago: I was pleased to listen to Dr. Gordon's paper on open reduction of mandibular fractures. I fear, however, that some of our dental colleagues would consider this treatment heresy. I was glad that his position in the British Army was similar to that in the Navy in this country.

We are more pleased with the patients whom we treated with open operation than with those whom we treated conservatively. This also applies to fractures of the malar bone. The reason that treatment has been more successful in the last few years is that we are treating not only the fracture but the patient as a whole, with the aid of the various chemotherapeutic agents.

One thing which Dr. Gordon mentioned was the late effect of no treatment of condylar fractures. I have not seen many late cases but patients who returned have come back with pain in the ear and pain in the ear when they chew, simulating the temporomandibular syndrome as described by Costen. This is relieved by resection of the condylar head.

807 Medical Arts Building.

CHEMOTHERAPY IN GAS GANGRENE

An Experimental Study

W. A. ALTEMEIER, M.D.

W. L. FURSTE, M.D.

AND

W. R. CULBERTSON, M.D.

CINCINNATI

CONFLICTING evidence obtained from numerous clinical and experimental reports has resulted in considerable confusion regarding the value and limitations of chemotherapy in gas gangrene. Although penicillin has been generally recognized as being more effective than the sulfonamide compounds, opinion is still divided as to its real value. Fisher and his associates,[1] who had an opportunity to observe its influence on the incidence and course of gas gangrene in four hundred and thirty-six military wounds characterized by extensive laceration of muscle, compound fractures, arterial damage, gross contamination and many retained foreign bodies, concluded that the role of penicillin should be the prevention of gas gangrene rather than its treatment when already established. Jeffrey and Thomson [2] enthusiastically recommended the parenteral administration of penicillin at the time of primary débridement and for the following three to five days. Among 28 patients with true gas gangrene who were treated in this manner there were 7 deaths, giving a mortality of 25 per cent. These authors believed that the clinical response provided convincing evidence that penicillin can arrest the progressive myositis but that radical surgical intervention is still the main factor in treatment. On the other hand, Cutler and Sandusky [3] concluded that penicillin used prophylactically in wounded and injured

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb. 22, 1947.

From the Department of Surgery of the University of Cincinnati College of Medicine and Cincinnati General Hospital. This paper is based in part on work done under grants from the National Institute of Health of the United States Public Health Service and the United States Army.

1. Fisher, G. H.; Florey, M. E.: Grimson, T. A., and Williams, P. H.: Penicillin in Clostridial Infections, Lancet **1**:395, 1945.

2. Jeffrey, J. S., and Thomson, S.: Penicillin in Battle Casualties, Brit. M. J. **1**:4, 1944.

3. Cutler, E. C., and Sandusky, W. R.: Treatment of Clostridial Infections with Penicillin, Brit. J. Surg. **32**:168, 1945.

flying personnel did not prevent the development of gas gangrene and that the effect of this agent in modifying the infection could not be evaluated on the basis of the slight evidence at hand. They reported on 7 patients with gas gangrene treated both locally and parenterally with penicillin, 5 of whom had received this therapy immediately after primary débridement. Their data indicated that proper surgical débridement is the major factor in both the prophylaxis and the therapy of gas gangrene. The experience of Patterson, Keating and Clegg [4] was similar in that the prophylactic use of penicillin in 8 cases failed to prevent the development of this infection. Conway,[5] who reported on 14 cases of gas gangrene among 4,040 casualties from the Philippine Islands, also concluded that penicillin is of no value in the prevention of gas gangrene. In the therapy of established gas gangrene, penicillin has been considered to be the most promising chemotherapeutic agent by numerous authors,[6] but the evidence for this is not clear. Meleney [6l] pointed out that penicillin has been used with encouraging results but only when given in large doses of 50,000 or even 100,000 units every two or three hours. In the same manner the United States War Department [6m] recommended 200,000 to 400,000 units per day for effective

4. Patterson, T. C.; Keating, C., and Clegg, H. W.: Experiences in the Prophylaxis and Treatment of Clostridial Infections in Casualties from the Invasion of Europe, Brit. J. Surg. **33**:74, 1945.

5. Conway, H.: Anaerobic Infection and Gangrene of War Wounds in Casualties of the Philippine Islands, Surgery **19**:553, 1946.

6. (*a*) Altemeier, W. A.: Penicillin in Surgery, South. M. J. **37**:494, 1944. (*b*) Harris, C. M., and Leviton, L. R.: Penicillin Treatment of Gas Gangrene, Am. J. Surg. **69**:391, 1945. (*c*) Herrell, W. E.: Penicillin and Other Antibiotic Agents, Philadelphia, W. B. Saunders Company, 1945. (*d*) Jeffrey, J. S., and Thomson, S.: Gas Gangrene in Italy: A Study of Thirty-Three Cases Treated with Penicillin, Brit. J. Surg. **32**:159, 1944. (*e*) Keefer, C. S., and Anderson, D. G.: Penicillin in the Treatment of Infections, New York, Oxford University Press, 1945. (*f*) Kepl, M. F.; Ochsner, A., and Dixon, J. L.: Two Cases of Clostridum Welchii Infection Treated with Penicillin, J. A. M. A. **126**:96 (Sept. 9) 1944. (*g*) Kolmer, J. A.: Penicillin Therapy, Including Tyrothricin and Other Antibiotic Therapy, New York, D. Appleton-Century Company, Inc., 1945. (*h*) Langley, F. H., and Winkelstein, L. B.: Gas Gangrene: Study of Ninety-Six Cases Treated in Evacuation Hospital, J. A. M. A. **128**:783 (July 14) 1945. (*i*) Lockwood, J. S., in Christopher, F.: Textbook of Surgery, ed. 4, Philadelphia, W. B. Saunders Company, 1945. (*j*) MacLennan, J. D., and MacFarlane, M. G.: Treatment of Gas Gangrene, Brit. M. J. **1**:683, 1944. (*k*) McKnight, W. B.; Loewenberg, R. D., and Wright, V. L.: Penicillin in Gas Gangrene: Report of Successfully Treated Case, J. A. M. A. **124**:360 (Feb. 5) 1944. (*l*) Meleney, F. L., in Christopher, F.: Textbook of Surgery, ed. 4, Philadelphia, W. B. Saunders Company, 1945. (*m*) Notes on Care of Battle Casualties, United States War Department, Technical Bulletin (TB Med. 147), Washington, D. C., Government Printing Office, March 1945. Jeffrey and Thomson.[2]

therapy. On the other hand, Odom [7] felt that penicillin's sole value lay in the control of associated secondary infection, and Conway [8] believed that it was of no value in the therapy of established gas gangrene in casualties from the Philippine Islands.

Experimental studies have not eliminated the confusion. In 1942 and 1943 McIntosh and Selbie [8] found penicillin to be effective in experimental infections produced by the intramuscular injection of 0.1 cc. of a 5 per cent solution of calcium chloride and 0.1 cc. of a washed suspension of Clostridium welchii prepared from eighteen hour cultures. The local injection of 34 units of penicillin in 24 mice at the time of the bacterial inoculation was followed by survival of 100 per cent of the animals. When therapy was delayed for two hours there was a survival of 92 per cent, but when it was delayed for three hours there was a survival of only 17 per cent. Similar observations were reported by Hac and Hubert [9] on experimental gas gangrene in mice produced by the intramuscular inoculation of an unwashed eighteen hour culture of Cl. welchii. Subcutaneous injections of penicillin in doses of 5 and 500 Oxford units given immediately reduced the mortality from 90 per cent in the controls to 46 per cent and 2 per cent respectively. Experiments carried out on a small number of guinea pigs supported the observations made in the mice.

Likewise, Siebenmann and Plummer [10] found that the local injection of 50 units of penicillin was effective in mice one hour after infection produced by the intramuscular injection of a suspension of Cl. welchii in a 5.0 per cent solution of calcium chloride but ineffective when the same dose was given in the opposite leg. However, when the dose in the noninfected leg was increased fivefold to 250 units, it became nearly as effective as the 50 units injected locally at the site of infection. A single intravenous injection of penicillin (250 units) was fairly effective when administered one hour after infection but ineffective when given as late as four hours after infection.

In the experiments of Dawson, Hobby, Meyer and Chaffee [11] with infections produced by intramuscular inoculations of guinea pigs with a 10 per cent solution of calcium chloride and toxin-free suspensions of

7. Odom, C. B.: Causes of Amputation in Battle Casualties with Emphasis on Vascular Injury, Surgery **19**:562, 1946.

8. McIntosh, J., and Selbie, F. R.: Combined Action of Antitoxin and Local Chemotherapy on Cl. Welchii Infection in Mice, Lancet **2**:224, 1943.

9. Hac, L. R., and Hubert, A. C.: Penicillin in the Treatment of Experimental Clostridium Welchii Infection, Proc. Soc. Exper. Biol. & Med. **53**:61, 1943.

10. Siebenmann, C. O., and Plummer, E.: Chemotherapy and Antitoxin Therapy of Experimental Cl. Welchii Infection in Mice, J. Pharmacol. & Exper. Therap. **83**:71, 1945.

11. Dawson, M. H.; Hobby, G. L.; Meyer, K., and Chaffee, E.: Penicillin as a Therapeutic Agent, Ann. Int. Med. **19**:707, 1943.

Cl. welchii, the injection of 666 units of penicillin subcutaneously protected all the animals receiving 0.1 cc. of a suspension of Cl. welchii spores (one to two minimum lethal doses) but none of those receiving 0.2 cc.

Dowdy, Sewell and Vincent [12] concluded in 1944 that penicillin was an effective agent in prophylaxis of experimental gas gangrene in dogs produced by the standardized injection of a mixture of various clostridia and the Staphylococcus aureus which was adjusted to produce death in a high percentage of the controls but not an overwhelming infection.

No report of the use of streptomycin in established infections produced by Cl. welchii has been found. Robinson, Smith and Graessle [13] found that the sensitivity of Cl. welchii to streptomycin in vitro was not considerable, a concentration of greater than 104 units per cubic centimeter being required for inhibition of growth. DeBakey and Pulaski [14] have reported the effect of streptomycin on infected wounds, one third of which were contaminated by Cl. welchii, but not in cases of clinical gas gangrene.

In all the animal experiments which have been summarized the infections were produced by the inoculation of bacterial cultures through hypodermic needles into healthy muscle, although in some instances calcium chloride was used as a local irritant. Infections produced under such conditions are different from those seen clinically, in which masses of devitalized and degenerated tissue are prominent characteristics. In our opinion, this difference is largely responsible for the discrepancy between the obvious effectiveness of penicillin in gas gangrene experimentally produced and its questionable value in the type occurring clinically. A method has therefore been devised of measuring accurately the value and limitations of chemotherapy in standardized experimental gas gangrene which is produced in the presence of crushed muscle and dirt and which simulates closely the conditions of the clinical type.

MATERIAL

Guinea pigs weighing 350 to 450 Gm. were chosen as the experimental animals because of their pronounced susceptibility to infection with Cl. welchii which resembles that of human beings. Cl. welchii was chosen as the test organism because of its occurrence alone or in

12. Dowdy, A. H.; Sewell, R. L., and Vincent, J. G.: The Prophylaxis and Therapeusis of Clostridial Infections (Gas Gangrene), New York State J. Med. **44**:1890, 1944.

13. Robinson, H. J.; Smith, D. G., and Graessle, O. E.: Chemotherapeutic Properties of Streptomycin, Proc. Soc. Exper. Biol. & Med. **57**:226, 1944.

14. DeBakey, M., and Pulaski, E. J.: An Analysis of the Experience with Streptomycin Therapy in United States Army Hospitals, Surgery **20**:749, 1946.

association with other bacteria in 56 to 100 per cent of a series of reported cases of gas gangrene.[15] The virulence of many strains of Cl. welchii obtained from a variety of sources including soil, clothing and contaminated or infected wounds was investigated by determining the minimal lethal dose for these animals. For most of the strains tested the virulence was either relatively low or extremely variable. A strain of high virulence known as BP6K was obtained from Dr. Milan Logan, of the department of biochemistry, but preliminary studies showed that the minimum lethal dose of this strain also fluctuated widely. Cultures which were grown in the pancreatic digest mediums developed by Logan showed prolific growth, with much turbidity and formation of gas, and were much more virulent than those grown in deep meat broth, brain broth or other mediums. When incubated for only four and one-half to six hours in the pancreatic digest mediums, they produced death in much higher dilutions than when incubated for eighteen to twenty-four hours. In addition it was found that weekly passage through pigeons was necessary to maintain the virulence at a high level, and this was routinely done by Dr. Logan and Dr. Tytell. It was therefore possible to standardize the virulence of a strain of Cl. welchii at a high level by incubating for four and a half to five and a half hours in pancreatic digest medium a culture of BP6K passed weekly through a pigeon.

The penicillin used was the commercial sodium salt presently available, and the streptomycin used was in the hydrochloride form. Each was prepared in solution with sterile isotonic solution of sodium chloride.

METHOD

The infection was produced by the inoculation of measured quantities of bacteria in closed wounds containing crushed muscle and sterilized dirt by the following method. The skin over the lower part of the back and the posterior lateral aspects of the thigh of a guinea pig was prepared by being shaved and scrubbed with soap and water for five minutes. After the induction of drop ether anesthesia, the preparation of the operative area was completed by the application of alcohol, ether and tincture of iodine. A sterile drape containing a hole 1.5 by 1.0 cm. was then applied to the prepared area. It was necessary to take these steps to eliminate or minimize the introduction of Cl. welchii spores normally resident on the skin or hair of the guinea pig.[16] Under aseptic precautions, with the use of gowns, gloves, cap and mask, an incision 1.0 cm. in length was made through the skin and subcutaneous tissues over the midportion of the posterolateral aspect of the right thigh and developed down to and beyond the femur. The muscles on each side of the wound were then crushed five times with a Kocher clamp and avulsed by twisting the clamp at an angle of 180 degrees. Into each wound 0.5 cc. (0.6 Gm.) of an autoclaved and finely divided mixture of soil and cinders was placed. The

15. Altemeier, W. A., and Furste, W. L.: Gas Gangrene: A Collective Review of the Literature, Surg., Gynec. & Obst., to be published.

16. Altemeier, W. A.: The Rapid Identification of the Clostridium Welchii in Accidental Wounds, Surg., Gynec. & Obst. **78**:411, 1944.

edges of the wound were then closed with interrupted fine black silk sutures to minimize leakage of the inoculum and subsequent secondary contamination. In a previous series of experiments [15] it had been determined that the presence of crushed muscle and dirt increased the virulence of Cl. welchii one million times. Serial dilutions of a four and a half to six hour culture of Cl. welchii were then made to the tenth power, sterile pancreatic digest medium being used as the diluent since this gave more uniform results than isotonic solution of sodium chloride. Finally 0.5 cc. of one of the higher dilutions, representing one or multiples of one minimum lethal dose, was injected through the skin into the area of crushed muscle and dirt through a 25 gage needle and a tuberculin syringe. The minimum lethal dose was considered to be 0.5 cc. of the highest dilution of a culture on a given day which killed within four and two-thirds days all the guinea pigs under the conditions of the experiment. In addition. 0.5 cc. of all lower dilutions had to kill the animal within the same unit of time.

Six experiments, each involving 69 to 75 guinea pigs, were carried out, four with penicillin and two with streptomycin. A total of 444 animals were used. After production of the standardized wounds in each experiment, the animals were divided into three groups of approximately 25 each, one group for controls used to establish a minimum lethal dose for that day under the conditions of the experiment, another for measurement of the chemotherapeutic agent's prophylactic value in a given dose and the third for determination of its therapeutic value. Penicillin or streptomycin was given intramuscularly every three hours for ninety-six hours after the operation, the first prophylactic dose being administered simultaneously with the inoculation of the bacteria into the wound containing crushed muscle and dirt and the first therapeutic injection being made six to eight hours after inoculation. In order to explore as fully as possible its value, the dose of penicillin was varied in the four experiments, 2,000, 8,000, 32,000 and 96,000 units per kilogram of weight being used every twenty-four hours. The dose of streptomycin was 44.44 and 136 mg. per kilogram every twenty-four hours. In each instance the twenty-four hour dose was divided into eight equal parts and then administered intramuscularly every three hours, the two forelimbs and left hindlimb being used alternately. No further operative procedure or other form of treatment was used. The animals and their wounds were then carefully observed and the date of death recorded in each instance. In this manner it was possible to determine the minimum lethal dose for that day and to measure accurately the effectiveness of the two chemotherapeutic agents in a severe form of experimental gas gangrene closely similar to the clinical type. The minimum lethal dose varied between 0.5 cc. of a 10^{-8} dilution and 0.5 cc. of a 10^{-10} dilution in the various experiments.

RESULTS

Penicillin Prophylaxis.—When a standard dose of 2,000 units of penicillin per kilogram of weight per day was used in animals inoculated with one to one thousand minimum lethal doses under the conditions described, no measurable effect was evident and all the animals died within two and two-thirds days at a slightly faster rate than the controls (figs. 1 and 2). On a basis of units per kilogram, this dose is comparable to 15,000 to 20,000 units every three hours in an adult human being. When the dose was increased four times to 8,000 units per kilogram, a definite beneficial effect was detected, the rate of death

being retarded and 16 per cent of the animals surviving at the end of four and two-thirds days. In the group of animals receiving 32,000 units per kilogram, or sixteen times the standard dose, the prophylactic value of penicillin became evident (fig. 2). The size and spread of the lesion were greatly diminished, and 64 per cent of the animals survived for the period of four and two-thirds days. An additional increase in the protective effect of penicillin was apparent when the dose was increased to 96,000 units per kilogram. The control of the rate of spread of the infection was obvious, the lesions being small and often insignificant compared with those in the controls. Ninety per cent of the animals

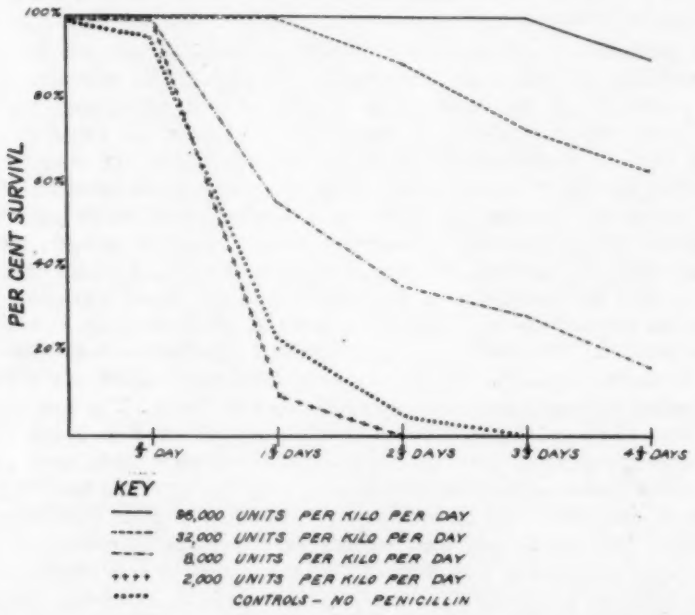

Fig. 1.—The progressive prophylactic effect of increasing doses of penicillin in gas gangrene produced experimentally in guinea pigs. Penicillin therapy was started immediately.

treated with this dose survived for four and two-thirds days even under the severe challenge of this type of infection.

Penicillin Therapy.—When the onset of penicillin therapy was delayed for six hours after challenge and when the infection was already established, the effectiveness of the drug was decreased. There was no significant difference between the appearance of the lesion or the survival rate in the control groups treated without penicillin and that in the groups receiving the standard dose of 2,000 units per kilogram, since all the animals died (fig. 3). Doses of 8,000 and 32,000 units per kilogram produced some retardation in the spread of the infection

Fig. 2.—*A*, typical appearance of the experimental gas gangrene developing in an untreated (control) animal receiving one minimum lethal dose of Cl. welchii. Death occurred in thirty hours after challenge; *B*, the ineffectiveness of immediate penicillin therapy in standard doses for experimental infection produced by one minimum lethal dose (0.5 cc. of 10^{-9} dilution) of Cl. welchii is clearly shown. A daily dose of 2,000 units of penicillin per kilogram was used in eight divided injections every three hours; *C*, showing the effectiveness of immediate penicillin treatment on experimental gas gangrene in an animal receiving one thousand minimum lethal doses of Cl. welchii. The infection has been obviously attenuated and kept localized by a daily dose of 32,000 units per kilogram in eight divided injections every three hours.

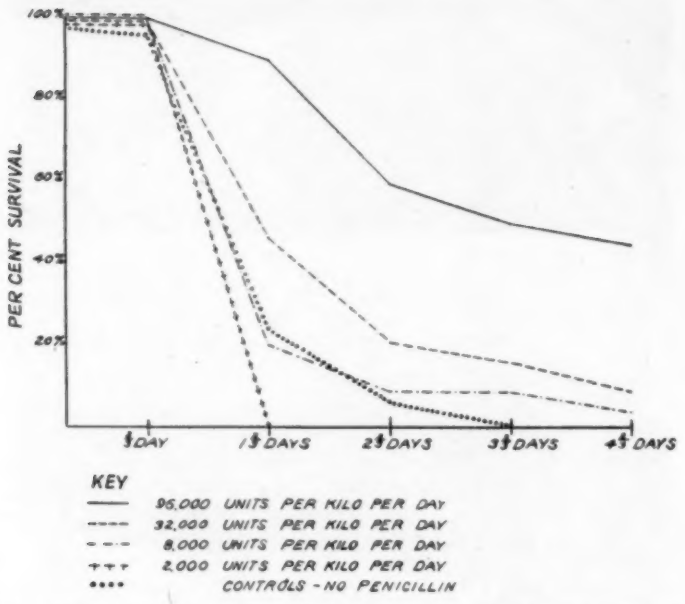

Fig. 3.—The definite and unquestionable beneficial therapeutic effect of massive doses of penicillin on the survival rate of animals challenged six hours before.

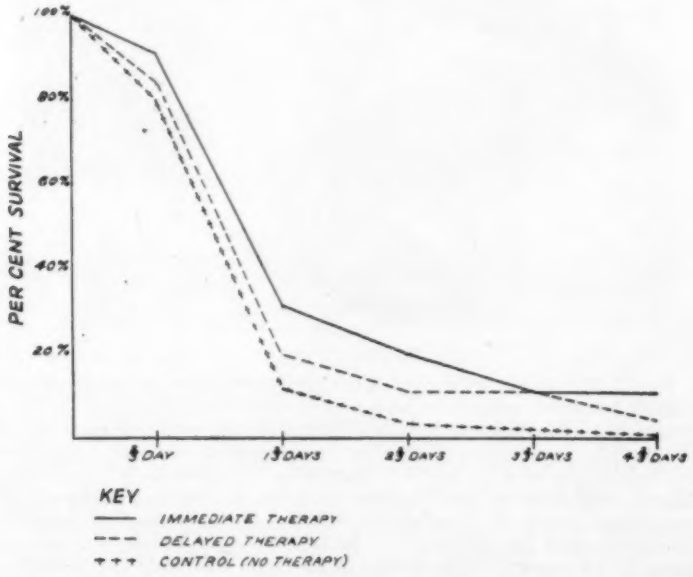

Fig. 4.—The prophylactic and therapeutic ineffectiveness of streptomycin in experimental gas gangrene when given in the moderately large dosage of 44.44 mg. per kilogram per day.

and in the rate of death, but less than 10 per cent of the animals survived for the four and two-thirds days. Massive doses of 96,000 units per kilogram produced an obvious effect on the course of the infection. The severity of the infection was diminished, as evidenced by the smaller size of the lesions, the better condition of the animals and the survival of 45 per cent of them during the four and two-thirds days.

When the period of observation was extended to fourteen days after challenge and ten days after cessation of penicillin therapy, all the animals died but 2.

Streptomycin Prophylaxis.—In the group of animals receiving 44.44 mg. of streptomycin per kilogram every twenty-four hours divided

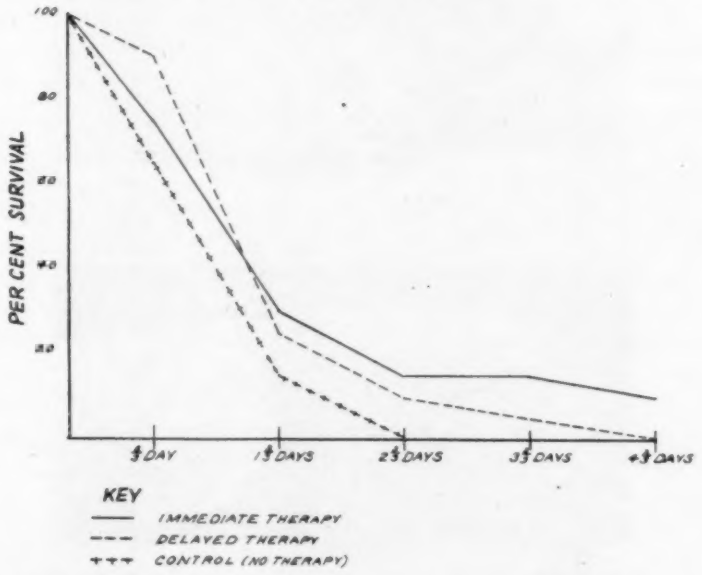

Fig. 5.—Ineffectiveness of large doses, 136 mg. per kilogram per day, of streptomycin in the prevention or treatment of experimental gas gangrene.

into doses given every three hours there was no significant difference in the severity of the infection or in the rate of death as compared with the occurrence in the control group receiving no treatment. Only 12.0 per cent of the treated animals survived for the four and two-thirds days. When the dose was increased to 136 mg. per kilogram every twenty-four hours, the result was approximately the same (figs. 4 and 5). Observations on the progress of the infection in the animals prior to their death showed no appreciable difference in the lesions of any group. All spread swiftly, with the production of discoloration, edema and gas in the tissues of the entire thigh, hip and, frequently, abdominal wall (fig. 6).

Streptomycin Therapy.—When streptomycin therapy with either 44.44 mg. or 136 mg. per kilogram every twenty-four hours was delayed for six to eight hours after inoculation of one to ten thousand minimum lethal doses of Cl. welchii, the infection, already established, progressed thereafter practically uninhibited, the treated animals appearing to be just as sick as the controls and dying at approximately the same rate (figs. 4 and 5).

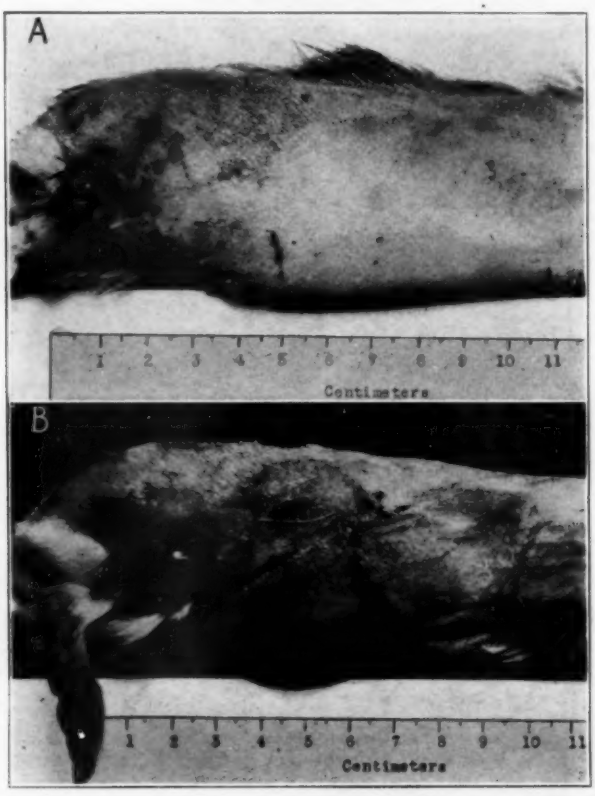

Fig. 6.—*A*, fulminating gas gangrene extending over abdominal wall in an animal receiving one hundred minimum lethal doses of Cl. welchii who was given intensive and immediate streptomycin therapy in daily amounts of 136 mg. per kilogram divided into eight doses given every three hours. Death occurred in nineteen hours. *B*, extensive gas gangrene produced by ten minimum lethal doses which was unaffected by similar treatment with streptomycin started eight hours after bacterial challenge. Death occurred in thirty-five hours.

COMMENT

An analysis of these experimental studies explains many of the discrepancies in the results of chemotherapy in gas gangrene. It is obvious that the experimental infection produced in the presence of crushed muscle and dirt is considerably different from that produced by the

simple injection of bacteria with or without local irritants into healthy muscle. It is not only much more severe but also much more refractive to therapy. Consequently, chemotherapeutic agents have been made to appear much more effective in the past than they really are when tested against experimental infections produced by simple injection of bacteria. In the severer form of gas gangrene in animals penicillin has proved to be the chemotherapeutic agent of choice, while streptomycin was found to have little or no value. It is important to note that penicillin was much more effective when used prophylactically than when used in infections already established. This emphasizes the advisability of starting parenteral administration of penicillin as soon after injury as possible and before débridement. The longer chemotherapy is delayed, the more limited the response to it will be.

It is also significant that under the challenge of severe infection penicillin had little or no measurable value when used either prophylactically or therapeutically in average dosage. Only when the dose was increased sixteen times did its effect prophylactically become obvious, and only when it was increased forty-eight times did its therapeutic effect become unquestionable. This probably explains, at least in part, many of the differences in the clinical results which have been obtained with penicillin. It is realized that this experiment has put penicillin to a most severe test not only because the wounds in which the infection was produced contained crushed muscle and dirt but also because they were closed with sutures and were not treated subsequently by surgical incision or excision. This was done purposely to eliminate the confusing effect of any other therapeutic factor. It would seem that early and adequate surgical treatment should still be considered the most important factor in the prevention of clinical gas gangrene and that parenterally administered penicillin may be expected to be a valuable therapeutic adjunct.

As demonstrated in these studies, massive doses of penicillin checked the invasive qualities of the infection, both retarding its development and limiting its spread under adverse conditions. This fact suggests that the early clinical use of penicillin in large doses up to 1,000,000 units every three hours will probably have the following effects: (1) limitation of the invasive qualities of the infection and prolongation of the period during which effective surgical procedures short of amputation can be done; (2) the possibility of amputation at lower levels, resulting in less mutilating sequelae, when amputation is necessary in advanced infections; (3) inhibition not only of the secondary bacterial invaders usually susceptible to penicillin but also of many of the organisms ordinarily resistant to average doses, and (4) marked reduction in the mortality.

SUMMARY

The effect of penicillin and streptomycin has been carefully measured in a series of experimental studies on a severe and standardized form of gas gangrene in animals simulating the type which develops clinically in man. Although streptomycin was found to have no significant therapeutic value, penicillin was shown to have a notable beneficial effect on the rate of development and the extensiveness of the infection as well as on the mortality. Since the effect of chemotherapy was greatly modified by the time of onset and the size of the dose in these experiments, it would seem advisable to administer penicillin parenterally as soon as possible and in conjunction with surgical treatment in persons with gas gangrene or with wounds of the type which predisposes to its development and to continue using it thereafter both preoperatively and postoperatively in large doses up to 1,000,000 units every three hours until the threat of this infection is over.

OSTEOCHONDROSARCOMA OF THE STERNUM

Use of Tantalum Plate as a Prosthesis

R. ARNOLD GRISWOLD, M.D.
LOUISVILLE, KY.

THE METAL tantalum has been shown to be inert and well tolerated by body tissues.[1] It has been widely used for the repair of defects following wounds of the skull sustained in war in the form of tantalum plate.[2] The material is also available and used as tantalum foil and tantalum suture material.[3] In the case to be presented a large sheet of tantalum 0.0125 inch (0.032 cm.) thick was used as a prosthesis after removal of the body of the sternum and a large part of the anterior thoracic wall for osteochondrosarcoma originating in the sternum. It was hoped that the tantalum plate might serve as a permanent prosthesis. However, the motion of the thoracic wall produced so much bleeding from the tissues surrounding the plate that formation of hematoma necessitated removal of the plate. The plate did, however, serve as a valuable temporary prosthesis to prevent paradoxic respiration and to tide the patient over the early postoperative period.

REPORT OF A CASE

K. F., a white farmer and laborer aged 41, was admitted to Norton Memorial Infirmary on Aug. 24, 1946, with the history of a tumor on the anterior surface of the sternum. This tumor had been first noticed about eighteen months previously, at which time it was about one sixteenth of an inch (0.16 cm.) thick and 2 inches (5 cm.) in diameter. It was firm, fixed and painless but had grown progressively larger, until at the time of the patient's admission to the hospital it measured 4 by 6 inches (10 by 15 cm.) and projected 3 inches (7.6 cm.) from the anterior surface of the sternum, lying in the midline and extending from the level of the third to the level of the sixth costal cartilage. With the exception of frequent attacks of dyspnea, the patient had no other complaints. His previous health had been excellent. He stated that in the course of his work he frequently held an

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From the Department of Surgery, University of Louisville School of Medicine.

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb. 22, 1947.

1. Carney, H. M., and Burch, J. C.: Proc. Soc. Exper. Biol. & Med. **51**: 147-148 (Oct.) 1942. Burke, G. L.: Canad. M. A. J. **43**:125-128 (Aug.) 1940. Pudenz, R. H.: Surgery **12**:791-797 (Nov.) 1942.
2. Woodhall, B., and Spurling, R. G.: Ann. Surg. **121**:649-671 (May) 1945.
3. Olson, C. T.: Indust. Med. **13**:917-920 (Nov.) 1944.

auger or a brace and bit against his chest. General examination of the patient showed the physical condition to be essentially normal with the exception that the heart was shifted slightly to the left and the contour of the chest was deformed by the tumor (figs. 1 and 2).

The roentgenologic report by Dr. J. C. Bell was as follows:

Roentgenograms of the chest and the sternum were made with the patient in various positions. There is an extensive destructive lesion involving the middle third of the sternum. A tumor mass extends posteriorly into the thorax a distance of almost 2 inches (5 cm.) and extends upward and downward a distance of almost 6 inches (15 cm.). The same tumor mass extends far anteriorly to the level of the thoracic wall, where a large tumor mass of soft tissue can be seen, within

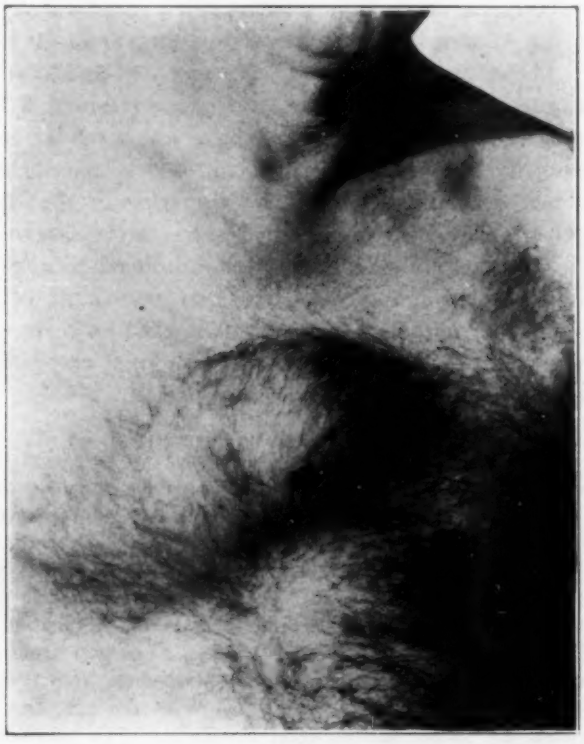

Fig. 1.—Anterior view of thorax.

which are many areas of calcification. There is definite destruction in the cortex of the anterior part of the sternum. The changes here are due to the presence of a tumor, presumably an osteochondroma, which in my opinion may very well have undergone a sarcomatous change. No evidence of destruction of the ribs is seen. No other abnormalities are noted (fig. 3).

Operation.—On Aug. 26, 1946, with the patient under anesthesia induced by endotracheally administered cyclopropane, oxygen and ether, the sternum and tumor were exposed through a "T" incision, the cross bar of the "T" being at the second costal cartilage and the vertical limb extending over the tumor down to the xiphoid. The skin flaps were reflected laterally away from the presenting

mass. The internal mammary vessels were exposed and ligated with silk in the second interspace on both sides. Subcutaneous bleeding was controlled by electrocoagulation. The third, fourth, fifth, sixth and seventh costal cartilages were divided 1 inch (2.5 cm.) from the tumor on both sides. The sternum was divided at the junction of the body and the manubrium. The tumor and sternum were retracted ventrally and dissected away from the mediastinal structures. Both pleural spaces were opened. Respiration was maintained by intermittent positive

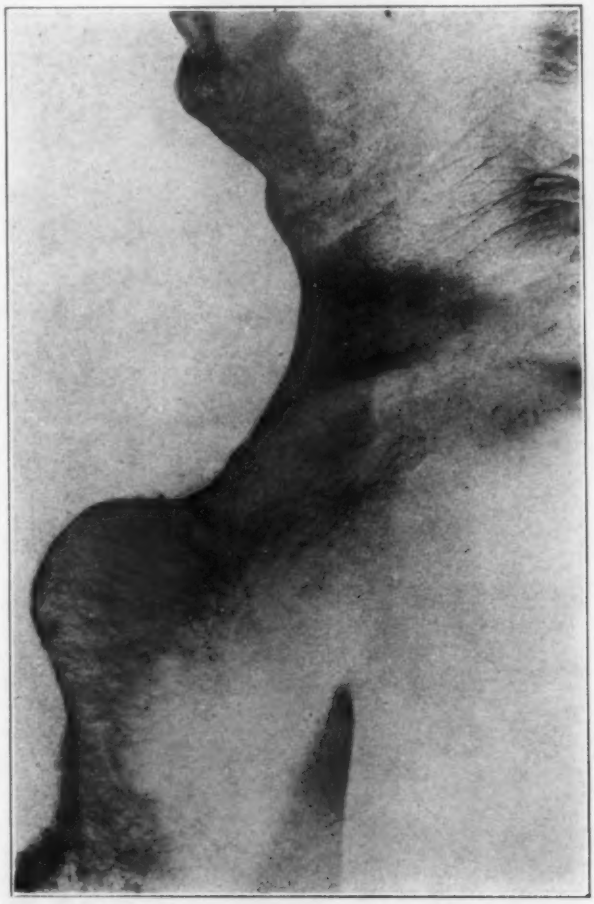

Fig. 2.—Lateral view of thorax.

pressure during the time that the chest was open. The lower end of the body of the sternum was detached at the xiphoid. Hemostasis was completed by silk ligatures and electrocoagulation.

The defect in the bony chest wall measured approximately 12.5 by 12.5 cm. At this time a tantalum plate was cut and fitted to the defect, overlapping the stumps of the costal cartilages, the manubrium and the xiphoid approximately 0.5 cm. Grooves were cut in the xiphoid, the manubrium and the stumps of the costal cartilages to allow the plate to be mortised into place under tension.

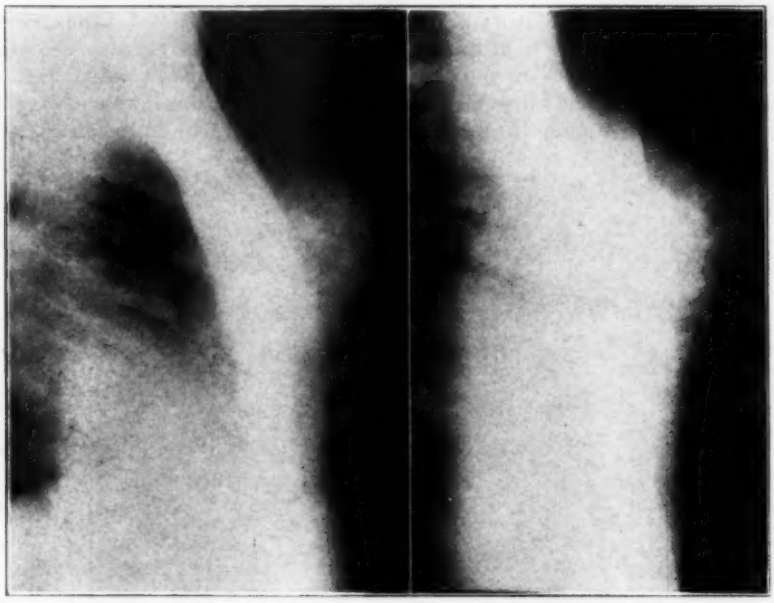

Fig. 3.—Lateral roentgenograms of different densities showing projection of tumor into the mediastinum and anteriorly.

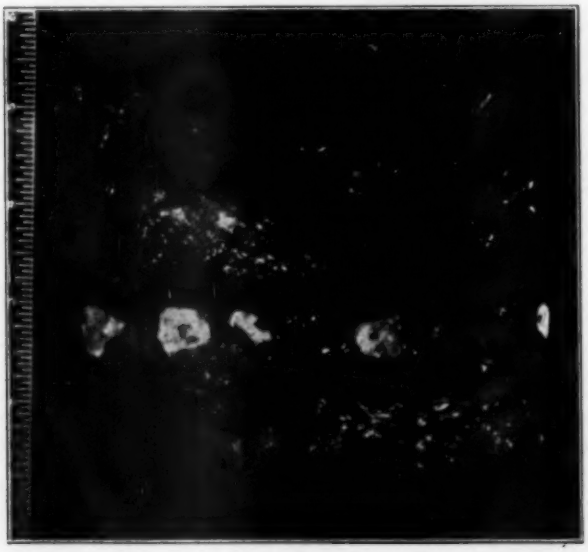

Fig. 4.—Lateral view of tumor showing projection anterior and posterior to sternum and stumps of costal cartilages.

Sutures of tantalum wire were used through the plate and the costal cartilages to add additional stability. Flaps of skin were replaced. The subcutaneous tissues were closed with interrupted silk ligatures and the skin closed in the same manner. Blood and air were aspirated through catheters in both pleural cavities. At the end of the operation the catheters were removed, giving airtight closure to the chest.

During the operation, whole blood and plasma were administered to maintain the level of blood pressure, and oxygen exchange was maintained by intermittent positive pressure.

Gross Observations.—The specimen (figs. 4 and 5) consisted of a large irregular firm ovoid mass which was projecting above and below the body of the sternum.

The stumps of five costal cartilages projected from the lateral margin. The mass itself, projecting above the sternum, measured 10 by 11 by 13.5 cm. in diameter. The

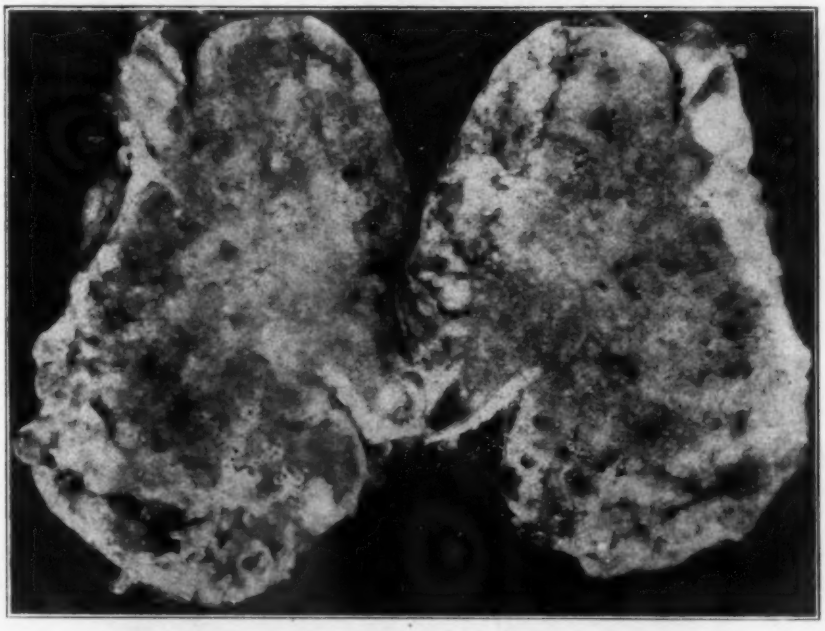

Fig. 5.—Longitudinal section. Lower end of body of sternum is shown in the lower center and upper end in the upper right and left corners.

portion on the other side of the ribs measured 9 by 6.5 by 3.5 cm. in diameter. Grossly, it was a firm multilobulated mass which contained numerous cystic gelatinous-like structures protruding from the lateral margin. Similar cartilage cysts were found in the substernal region. On section the tumor was grayish pink and somewhat gelatinous and there were areas of hemorrhage situated in the central portion. The tumor seemed to arise from the body of the sternum, which showed invasion and destruction.

Microscopic Observations.—The section is composed mostly of cartilage tissue with deep basophilic-staining stromas, and the nuclei are markedly pyknotic. These were located in the lacunas, which varied in size and shape. These portions of cartilage were arranged in irregular shapes, and there were intervening spaces in which

fat cells and red blood cells could be seen. In one section cartilage arising from osteoid tissue was seen. Numerous vascular channels appeared between the trabeculae of bone, and there was occasional evidence of bone formation. The adjacent tissue had the appearance of fibrous stroma, in which the nuclei were large and appeared to be undergoing marked proliferation.

Diagnosis.—The diagnosis was osteochondrosarcoma.

Postoperative Course.—The immediate postoperative course was uneventful except for transient pain in the chest, tachycardia and dyspnea. For the first ten days the tantalum plate buckled with each respiratory movement. Later the

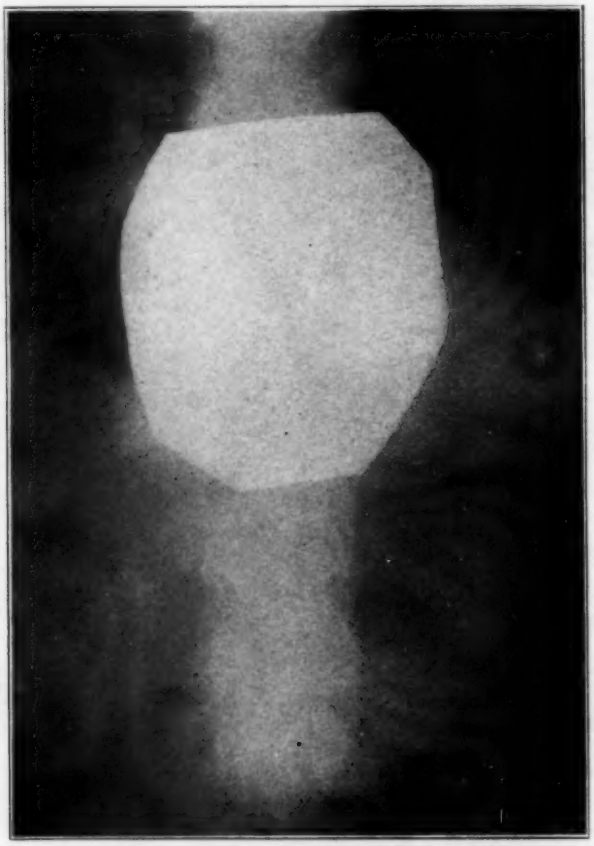

Fig. 6.—Roentgenogram made six weeks postoperatively showing tantalum plate in position.

thickening of surrounding tissues stabilized the plate so that buckling could neither be heard nor felt. Roentgenograms made on the seventh postoperative day showed a considerable amount of fluid in both pleural spaces. Several thoracenteses were done for accumulation of sterile fluid in the pleura. On the tenth postoperative day a small amount of serosanguineous drainage occurred from the vertical limb of the incision. Fifteen days postoperatively, tenderness of the left calf, with edema, developed. The following day the left femoral vein was ligated under local anesthesia. The edema and tenderness in the leg improved.

Thoracenteses were continued at infrequent intervals until September 19. Roentgenograms of the chest on this date and on October 11 showed no further effusion and only a slight amount of pleural thickening (fig. 6). The incision continued to drain serosanguineous fluid, and on September 29 several large clots were evacuated through an opening in the inferior angle of the incision. The patient continued to improve, although slight drainage persisted (fig. 7). Several courses of penicillin were given to prevent and control infection. However, clots and blood continued to accumulate about the plate, apparently because of the motion of the thoracic wall. For this reason the plate was removed on November 13.

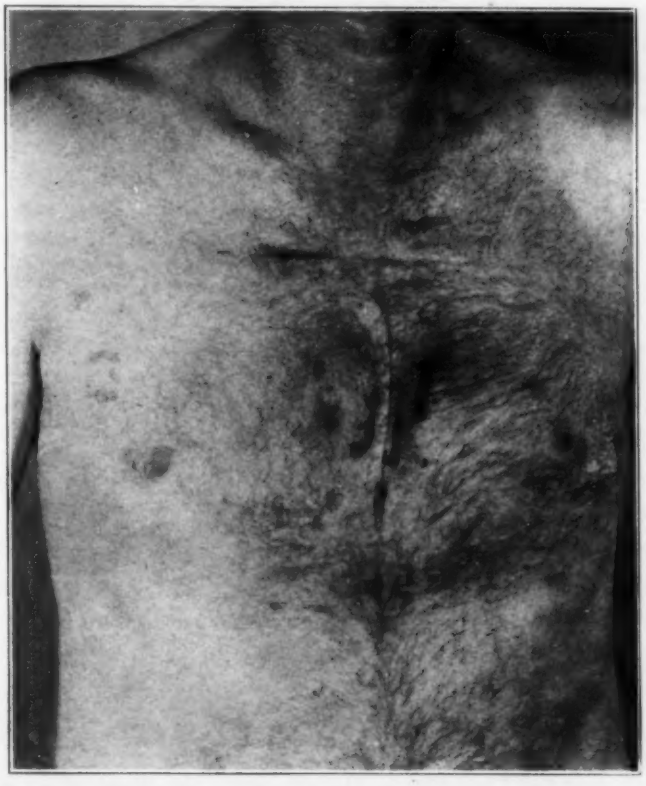

Fig. 7.—Postoperative view showing small sinuses which drained clot and old blood until the plate was removed.

After removal of the plate there was no evidence of paradoxic respiration and the soft tissue of the anterior thoracic wall had become thickened and toughened. Drainage ceased, and the wound healed.

COMMENT

The large tantalum plate used in this patient was completely effective in preventing paradoxic respiration and maintaining good respiratory exchange during the postoperative period. The plate buckled with

each respiration during the early postoperative period. A plate 0.020 inch in thickness would have been preferable. It did not serve as a permanent prosthesis because of continuous bleeding around it caused by the trauma from respiratory movements. The plate could have been removed as early as three weeks postoperatively, at which time there was sufficient stabilization of the anterior thoracic wall and mediastinum to permit normal respiratory exchange.

SUMMARY

A case is reported in which a large portion of the anterior thoracic cage was removed because of osteochondrosarcoma of the sternum. A large tantalum plate was fitted into the defect. This plate functioned satisfactorily as a temporary prosthesis.

HERNIAL REPAIR USING COOPER'S LIGAMENT

Follow-Up Studies on Three Hundred and Sixty-Seven Operations

HENRY N. HARKINS, M.D.
SEATTLE
AND
RICHARD H. SCHUG, M.D.
DETROIT

DURING the past seven years we have studied a method of herniorrhaphy which utilizes Cooper's ligament in situations in which one would customarily use Poupart's ligament. This method was first advocated by Lotheissen [1] for use in femoral hernia and was extended to direct and some indirect hernias on the basis of the anatomic studies of McVay and Anson [2] (1940).

The conventional operations for the repair of hernia in the groin generally involve two principles: 1. Indirect inguinal, direct inguinal and femoral hernias are repaired by different methods. 2. When an inguinal approach is used, some structure is sutured to Poupart's ligament. The present method disregards both of these tenets and consists, in brief, of two essential features: 1. Those structures usually sutured to Poupart's ligament are fastened instead to Cooper's ligament (the ligamentum pubicum superius B N A). 2. Essentially the same technic can be used for all hernias of the groin, whether they are indirect or direct, inguinal or femoral, simple, sliding, incarcerated or strangulated.

The present study includes three hundred and sixty-seven hernias in the groin treated by the technic which utilizes Cooper's ligament during the seven year period subsequent to April 1940.

Read at the fourth annual meeting of the Central Surgical Association, Chicago, Feb. 22, 1947.

From the Department of Surgery, Johns Hopkins University and the Johns Hopkins Hospital, Baltimore, and the Division of General Surgery, Henry Ford Hospital, Detroit.

1. Lotheissen, G.: Zur Radikaloperation de Schenkalhernien, Centralbl. f. Chir. **25**:548-550, 1898.

2. Anson, B. J., and McVay, C. B.: Inguinal Hernia: I. The Anatomy of the Region, Surg., Gynec. & Obst. **66**:186-191 (Feb. 1) 1938; Aponeurotic and Fascial Continuities in the Abdomen, Pelvis and Thigh, Anat. Rec. **76**:213-231 (Feb. 24) 1940; Composition of the Rectus Sheath, ibid. **77**:213-225 (June 25) 1940.

HISTORICAL DATA

The principle of suturing the transversalis fascia and the attached structures to Cooper's ligament is not new. Apparently Narath [3] was the first to use this technic, but especial credit should go to Lotheissen (1898), who made the first written report. Lotheissen used the technic in 12 cases of femoral hernia, with no recurrences, the longest period of observation being one year. His method involved an exposure of Cooper's ligament by slight lateral retraction of the femoral vessels. He then sutured the muscular edge of the internal oblique to Cooper's ligament with four to five heavy silk stitches. Lotheissen refers to this step of the procedure as follows: "Then comes the most difficult act, the drawing out through the ligament of Cooper."

Other writers on the subject were Fischer,[4] Groves,[5] Stetten,[6] Andrews,[7] Keynes,[8] Dickson,[9] McVay,[10] Goinard,[11] McClure and Fallis,[12] Amendola,[13] Neuhof,[14] McVay and Anson,[15] Harkins, Szilagyi, Brush and Williams,[16] Harkins and Swenson,[17] Hyde,[18] Sauer,[19] Clark

3. Narath (1898), cited by Lotheissen.[1]

4. Fischer, H.: Lotheissen's Operation for Femoral Hernia, Ann. Surg. **69**: 432-434 (April) 1919.

5. Groves, E. W.: A Note on the Operation for the Radical Cure of Femoral Hernia, Brit. J. Surg. **10**:529-531 (April) 1923.

6. Stetten, DeW.: Further Observations on a Modified Inguinal Hernioplasty Technic, with Completed Utilization of the Aponeurosis of the External Oblique, Ann. Surg. **78**:48-60 (July) 1923.

7. Andrews, E.: The Closure of Large Femoral and Inguinofemoral Defects: The Result of Destruction or Relaxation of Poupart's Ligament, Surg., Gynec. & Obst. **39**:754-759 (Dec.) 1924.

8. Keynes, G.: The Modern Treatment of Hernia, Brit. M. J. **1**:173-179 (Jan. 29) 1927.

9. Dickson, A. R.: Femoral Hernia, Surg., Gynec. & Obst. **63**:665-669 (Nov.) 1936.

10. McVay, C. B.: An Anatomic Error in Current Methods of Inguinal Herniorrhaphy, Ann. Surg. **113**:1111-1112 (June) 1941.

11. Goinard, P.: Cure radicale de certaines hernies inguinales par fixation du tendon conjoint au ligament de Cooper, Presse méd. **47**:872 (May 31) 1939.

12. McClure, R. D., and Fallis, L. S.: Femoral Hernia: Report of Ninety Operations, Ann. Surg. **109**:987-1000 (June) 1939.

13. Amendola, H.: Repair of Hernia with a Silk Binding Stitch, read before the New York Surgical Society, Oct. 8, 1941.

14. Neuhof, H.: An Operation for Inguinal Hernia Based upon the Utilization of Cooper's Ligament, Surgery **12**:128-132 (July) 1942.

15. McVay, C. B., and Anson, B. J.: Fundamental Error in Current Methods of Inguinal Herniorrhaphy, Surg., Gynec. & Obst. **74**:746-750 (March) 1942.

16. Harkins, H. N.; Szilagyi D. E.; Brush, B. E., and Williams, R.: Clinical Experiences with the McVay Herniotomy: One Hundred and Thirty-One Personal Cases, Surgery **12**:364-377 (Sept.) 1942.

(Footnotes continued on next page)

and Hashimoto,[20] McLaughlin and Brown,[21] Mattson,[22] Blodgett,[23] Burton [24] and Garner.[25]

The article by McVay and Anson [18] summarizes the coordinated views of these men concerning the true nature of inguinal hernia and the proper repair of the condition. They stated:

> In the more common types of inguinal herniorrhaphy the transversalis fascia and, variously, the transversus abdominis and internal oblique layers are sutured to the inguinal ligament, providing a poor substitute for their normal insertion. The inguinal ligament is not the insertion of the transversalis fascia, the transversus abdominis aponeurosis, or the internal oblique aponeurosis; its relationship to these structures is simply one of contiguity. From an anatomical standpoint this is reason enough for endeavoring to find some other structure for anchorage. Moreover, from a surgical point of view, the inguinal ligament does not make a suitable substitute for their regular insertion because of its character. . . . In the repair of large indirect and direct inguinal hernias, it is recommended that the inguinal layers be sutured to Cooper's ligament and not to the inguinal ligament. It is pointed out that the inguinal ligament is neither the normal insertion of the inguinal strata nor a suitable substitute for such attachment; on the contrary, the superior pubic ligament, Cooper's ligament, which is the normal insertion, is readily accessible, intrinsically strong, and directly fixed to bone.

The anatomic studies of McVay done under the direction of Anson in the Department of Anatomy of Northwestern University and later

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17. Harkins, H. N., and Swenson, S. A., Jr.: A Cooper's Ligament Herniotomy: Clinical Experience in Three Hundred and Twenty-Two Consecutive Cases, S. Clin. North America **23**:1279-1297 (Oct.) 1943. Swenson, S. A., Jr., and Harkins, H. N.: The Surgical Treatment of Recurrent Inguinal Hernia with Special Reference to a Cooper's Ligament Herniotomy and the Use of Free Fascia Grafts, Surgery **14**:807-818 (Dec.) 1943. Harkins, H. N.: The Surgical Treatment of Hernia, New Orleans M. & S. J. **99**:47-49 (Aug.) 1946.

18. Hyde, T. L.: Inguinal Herniorrhaphy, Am. J. Surg. **69**:182-189 (Aug.) 1945.

19. Sauer, I.: Hérnia inguinal: Leus dismorfismos e maneira de corrigí-los (técnica de Lotheissen-McVay), Rev. méd. munic. **6**:419-433 (May-June) 1945.

20. Clark, J. H., and Hashimoto, E. I.: Utilization of Henle's Ligament, Iliopubic Tract, Aponeurosis Transversus Abdominis and Cooper's Ligament in Inguinal Herniorrhaphy: A Report of One Hundred and Sixty-Two Consecutive Cases, Surg., Gynec. & Obst. **82**:480-484 (April) 1946.

21. McLaughlin, C. W., Jr., and Brown, J. R.: Inguinal Hernias and Allied Defects in Naval Recruits: An Analysis of 1,406 Patients Admitted to Surgical Treatment, Surgery **19**:267-274 (Feb.) 1946.

22. Mattson, H.: Use of Rectus Sheath and Superior Pubic Ligament in Direct and Recurrent Inguinal Hernia, Surgery **19**:498-503 (April) 1946.

23. Blodgett, J. B.: A Study of the Effects of Early Rising in the Post-operative Period, read at the meeting of the Society of University Surgeons, Boston, Feb. 13, 1947.

24. Burton, C. C.: Rationale and Factors for Consideration in Cooper's Ligament Hernioplasty, Internat. Abstr. Surg. **85**:1-8 (July) 1947.

25. Garner, A. D.: Inguinal Hernia: An Analysis of 2,643 Operations, Am. J. Surg. **74**:14-23 (July) 1947.

applied to the surgical repair of hernia by McVay are succinctly expressed in the previous paragraph. After hearing a lecture by McVay in April 1940, one of us (H. N. H.) began the present study. After applying McVay's principles to the surgical repair of three hundred and sixty-seven hernias of the groin we have little to find at variance with his opinions.

COOPER'S LIGAMENT (LIGAMENTUM PUBICUM SUPERIUS)

The relationships between Cooper's ligament and the pubis below and Poupart's (inguinal) ligament above are clearly shown in figures 1

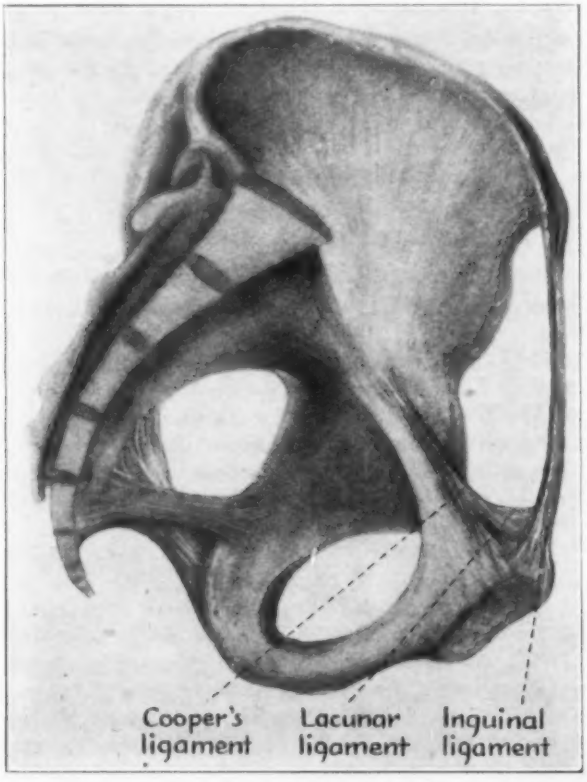

Fig. 1.—Cooper's ligament. View of the left half of the pelvis with attached ligaments. The relationships between the firmly anchored Cooper's ligament and the loose inguinal ligament are clearly shown.

and 2. Cooper's ligament has received relatively little attention in the literature. Seelig and Tuholske [26] stated: "It is equally unfortunate

26. Seelig, M. G., and Tuholske, L.: The Inguinal Route Operation for Femoral Hernia, with a Supplementary Note on Cooper's Ligament, Surg., Gynec. & Obst. **18**:55-62 (Jan.) 1914.

that probably the most important structure utilized in the closure of the femoral ring, namely,Cooper's ligament, is not only not pictured in any of the anatomies but also is not adequately described in most of them." Cooper's ligament was first described by Sir Astley Cooper [27] when he pictured the os pubis as being "covered by a ligamentous expansion, which forms a remarkably strong production above the linea iliopectinea, extending from the tuberosity of the pubis outward and projecting from the bone over that line."

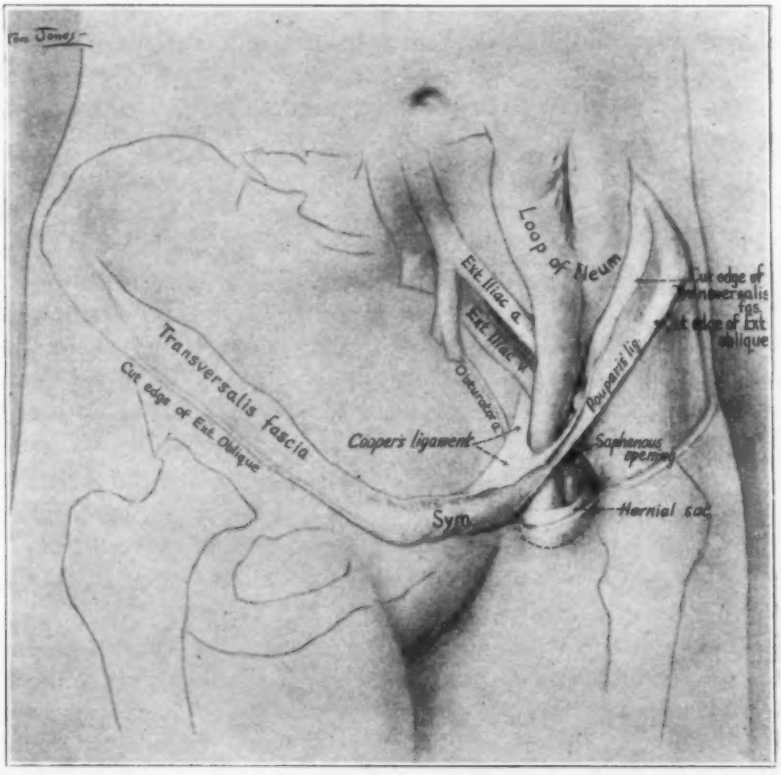

Fig. 2.—The relationship between femoral hernia and Cooper's ligament. (From Seelig and Tuholske: *Surg., Gynec. & Obst.* **18**:57, 1914.)

SELECTION OF CASES

In the period between April 24, 1940, and June 30, 1943, three hundred and twenty-two operations utilizing Cooper's ligament were done at the Henry Ford Hospital. In the period from July 1, 1943, to Jan. 12, 1947, forty-five such operations were done at the Johns Hopkins Hospital.

27. Cooper, A. (1804), cited by Seelig and Tuholske.[26]

During the period from April 24, 1940, to Aug. 31, 1941, the procedure was used by one of us (H. N. H.) in the treatment of only large indirect, direct or femoral hernias. During the entire period of study, the procedure was applied by the assistants only in the more difficult cases. Thus any selection of material was to the distinct disadvantage of the technic utilizing Cooper's ligament, the simpler hernias being treated by the better known Bassini method or by the original Halsted method.

From Sept. 1, 1941 until the close of the study on Jan. 12, 1947 (a period of over five years) one of us (H. N. H.) used the Cooper ligament technic in all cases except 1; in this instance a simple congenital hernia in a young man with strong fascial structures was operated on in October 1946 by the modified Halsted method without transposition of the cord.

TECHNIC

General Principles.—The general principles of Cooper's ligament technic of repair of hernia as applied by us include the following:

1. Silk sutures were used throughout in all cases. In no instance in the series at the Henry Ford Hospital was a single silk suture extruded from the wound. In the 45 cases in the series at the Johns Hopkins Hospital infected silk had to be removed from the hernial wounds in 2. Except for purse-string sutures, all stitches were of the interrupted type.

2. Spinal anesthesia was employed in most cases. It is felt that the greater relaxation given by this type of anesthesia outweighs its possible disadvantages. Occasionally supplementary anesthesia with gas, oxygen and ether was employed; in older patients or in others in whom the risk was poor, local anesthesia was preferred.

3. Skin towels fastened to the edges of the wound were used in all instances. In the series at the Henry Ford Hospital shaving of the skin and preliminary sterile preparations were done the evening before, followed by the application of a 3.5 per cent solution of iodine at the time of operation. In the group of patients at the Johns Hopkins Hospital the shaving and the other preparations were done at the time of operation.

4. Rest in bed for twelve days was advocated at the Henry Ford Hospital in cases of simple unilateral hernia, with discharge from the hospital on the fourteenth day. Patients with bilateral hernia were kept in bed for fifteen days and those with recurrent hernia for nineteen days. Return to full manual labor was permitted in five weeks for patients with simple hernia and in six weeks for the patients with bilateral or recurrent hernia. During the past two years, almost all patients have been encouraged to get out of bed in less than twenty-four hours after operation.

5. The time required for the operation is no greater than that for the more conventional procedures. The only special equipment needed is a round small curved Mayo needle (no. 6 or 7) and a good needle holder. A Bland or a Jones needle holder is desirable but not absolutely essential.

STEPS.—The repair of hernia in the groin which utilizes Cooper's ligament can be divided into ten steps. A step by step outline of the procedure follows:

1. *Exposure of the Cord and Opening of the Indirect Sac.*—The incision in the skin is made from 1 cm. medial to the anterosuperior

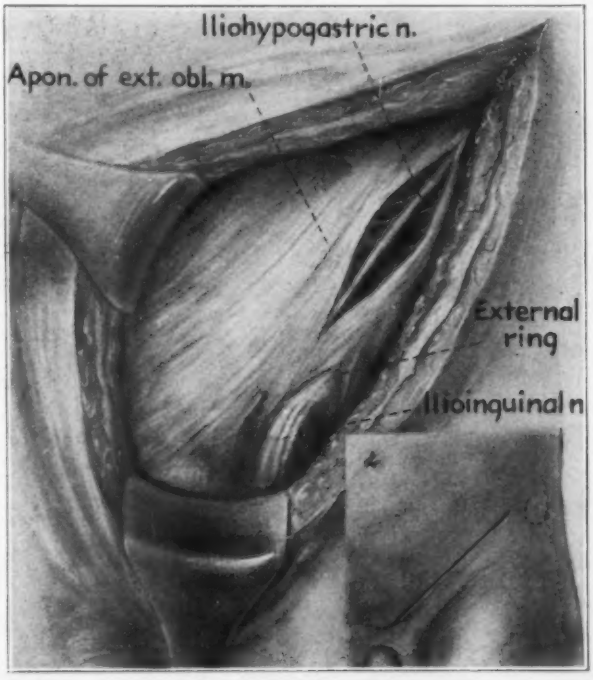

Fig. 3.—Cooper's ligament herniorrhaphy—incision of the skin and beginning of incision of the external oblique aponeurosis. The external oblique aponeurosis is usually opened in the direction of its fibers so that the opening will be even with the upper border of the external ring. The underlying iliohypogastric nerve is carefully avoided. (From *S. Clin. North America*, October 1943.)

iliac spine to over the pubic spine, which exposes the external oblique aponeurosis. The external ring is exposed and the external oblique aponeurosis split in the direction of its fibers even with the upper border of the ring to allow for an adequate lower flap. This splitting with the scalpel is best begun 3 cm. from the ring, as shown in figure 3, to avoid the nerves where they are adherent to the ring. The split is then extended laterally and upward with scissors and then more carefully downward in the direction of the external ring after the iliohypogastric

nerve, which is often adherent to the under surface of the external oblique aponeurosis at this level, has been carefully peeled away. When cutting occurs accidentally, it is usually near the external ring, and it may be prevented by approaching the latter from the lateral side. The cord and the surrounding structures are then separated from the lower leaf of the external oblique aponeurosis and Poupart's ligament and then from the region of the pubic spine and conjoined tendon so that finally the cord is freed entirely except at both ends. The indirect sac, which is always present even in normal persons, is located upward and medially from the internal ring.

In all cases, whether the hernia is indirect inguinal or femoral, the indirect sac is opened. In many cases of direct inguinal hernia or femoral hernia the indirect sac will be normal in size, but it can always be found above and medial to the cord. In cases of complete indirect inguinal hernia of the congenital type or in cases in which the hernial sac is long the latter is cut across near the internal ring and separated from the cord. The proximal end is closed by an internal purse-string suture, as outlined later, while the distal end is left in place. Many surgeons are of the belief that to leave the distal sac in place will cause hydrocele. This has not been our experience, and we believe that the hematomas that result from the removal of the distal sac are far more disastrous than any theoretic occurrence of hydrocele.

2. *Exploration of Hesselbach's Triangle and of the Femoral Ring.*—Once the indirect sac is opened, it is a simple matter to to insert the gloved finger and feel Hesselbach's triangle for a direct weakness or obvious direct hernia and to feel the femoral ring. It is indeed surprising how few surgeons will take the extra thirty seconds to perform this exploration, and many femoral and direct hernias that "recur" are overlooked because this maneuver was not performed. Exploration with the finger tip as shown in figure 4 of the femoral ring and Hesselbach's triangle should be an assential feature of all hernial repairs.

3. *Hoguet's Maneuver—Transposition of Direct or Femoral Sacs Into the Indirect Sac.*—If a direct sac is present as shown in figure 5, it should be transposed laterally to the inferior epigastric vessels by the technic of Hoguet [28] (1920), which has since been popularized by Fallis.[29] Thus, the direct and indirect sacs are converted into one. This step may be described in Hoguet's own words as follows: "By traction outward on the indirect sac, all of the peritoneum of the direct sac may be pulled external to the vessels and the two sacs converted into one. An indirect sac can always be found in these cases, although it may be very

28. Hoguet, J. P.: Direct Inguinal Hernia, Ann. Surg. **72**:671-674 (Dec.) 1920.

29. Fallis, L. S.: Inguinal Hernia: A Report of 1,600 Operations, Ann. Surg. **104**:403-418 (Sept.) 1936; Direct Inguinal Hernia, ibid. **107**:572-581 (April) 1938.

small." The same procedure may be used to convert a femoral sac into an indirect sac, as practiced by McClure and Fallis.[12] This maneuver is extremely useful. In general, no matter how large a direct sac is it is not opened but is merely transposed. In the case of large direct sacs the transversalis fascia can be infolded with numerous interrupted silk sutures. One advantage of not opening a direct sac is that the danger of opening the bladder is largely obviated. In some instances all three sacs can be converted into a single indirect sac, which in turn can always be dealt with as described in step 4.

4. *Internal Purse-String Closure of Indirect Sac.*—The indirect sac, whether it is simple or enlarged by the added conversion of direct and

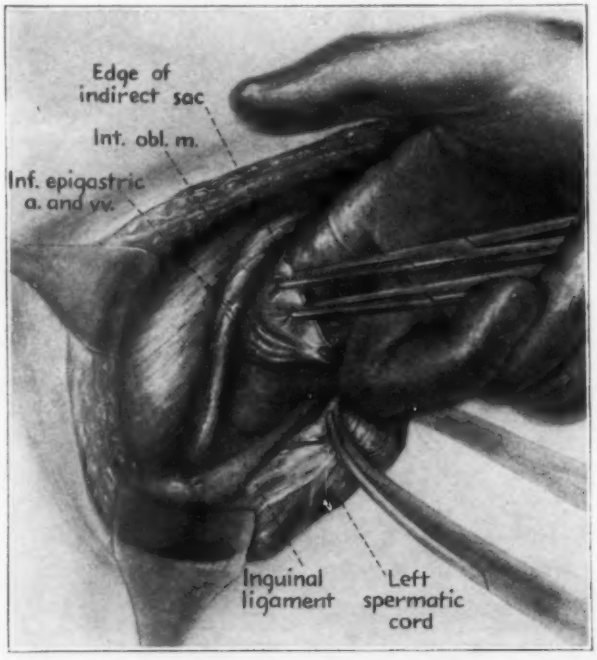

Fig. 4.—Cooper's ligament herniorrhaphy—exploration through the opened indirect sac. The latter is always opened and any femoral or direct sac is transposed by the method of Hoguet to become part of the indirect sac. The tip of the examining finger is in a small direct sac. (From *S. Clin. North America*, October 1943.)

femoral sacs, is then closed with an internal purse-string suture of medium or heavy silk, as shown in figure 6. Many stitches are taken with a round noncutting needle so as to include all crevices. Such a closure is done as high as possible to prevent indirect recurrences.

5. *Plastic on the Internal Ring—MacGregor's Maneuver.*—When the free ends of the purse string are cut and the peritoneum snaps back, the defect in the transversalis fascia at the internal ring is seen to be

large and in many instances will admit even three or four fingers. The fascia is grasped with Allis clamps at numerous points around the internal ring above and medially as far as the inferior epigastric vessels—but not inferior to the cord—and a second partial or semilunar purse-string suture of medium or heavy silk is made in the transversalis fascia. This ensures a snug fit around the cord, but the purse string itself does not surround the cord. Essentially this step involves the suturing of the transversalis fascia, Henle's ligament and cremaster muscles together. Occasionally the conjoined tendon may be included in the sutures, but the shelving edge of Poupart's ligament should not be

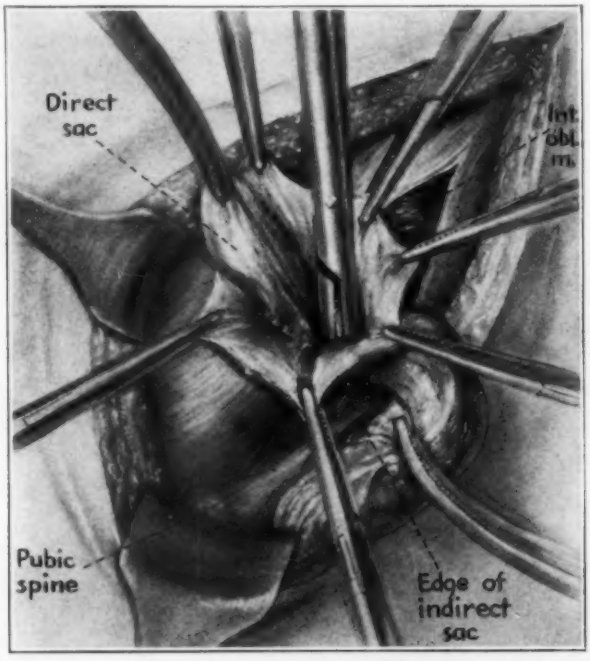

Fig. 5.—Cooper's ligament herniorrhaphy—Hoguet's maneuver. The direct sac has now been transposed and the gauze-tipped Küttner dissector is holding back the intestines. (From *S. Clin. North America,* October 1943.)

included since the normal and desirable retractile sphincter-like action of the internal ring demonstrated by MacGregor [30] would be interfered with. The use of Henle's ligament has been especially described by Clark and Hashimoto.[20]

30. MacGregor, W. W.: The Demonstration of a True Internal Inguinal Sphincter and Its Etiologic Rôle in Hernia, Surg., Gynec. & Obst. **49**:510-515 (Oct.) 1929; The Fundamental Operative Treatment of Inguinal Hernia, ibid. **50**: 438-440 (Feb.) 1930; Observations on the Surgical Treatment of Hernia, Ann. Surg. **122**:878-884 (Nov.) 1945.

6. *Relaxation of the Internal Oblique Muscle.*—The inner layer of the anterior rectus fascia is usually split for a distance of about 3 inches (7.6 cm.) from a point 2 cm. above the pubic spine upward and laterally. This is done almost exactly as described by Rienhoff [31] and as shown in figure 7. The external oblique is lifted up by the assistant and the internal oblique cut just lateral to the junction of the two to where they form the linea alba. The rectus and pyramidalis muscles are exposed. The iliohypogastric nerve and the adjoining nerves and vessels which enter the rectus muscle through the internal oblique aponeurosis at this point can be avoided easily. This relaxation allows the internal oblique

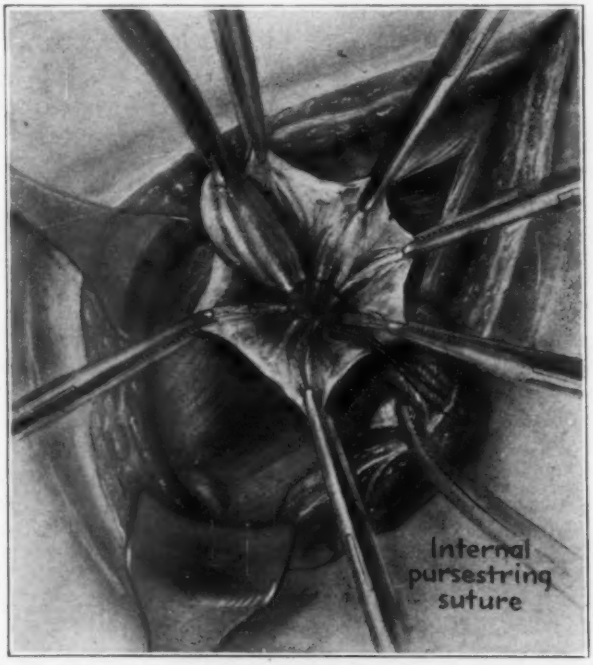

Fig. 6.—Cooper's ligament herniorrhaphy—internal purse-string suture. This suture completely closes the sac and by small bites obliterates all its folds. The redundant sac (proximal to its division and distal to the purse-string suture) is usually placed inside the internal ring but, if large, may be excised. (From *S. Clin. North America,* October 1943.)

and the attached transversalis fascia to be pulled down for the subsequent repair without tension.

7. *Sutures Into Cooper's Ligament.*—The "red" muscle of the internal oblique is entirely disregarded and even may be excised for convenience where it overlies the "conjoined tendon." Usually it is

31. Rienhoff, W. F., Jr.: The Use of the Rectus Fascia for Closure of the Lower or Critical Angle of the Wound in the Repair of Inguinal Hernia, Surgery **8**:326-339 (Aug.) 1940.

elevated with a small retractor and the "conjoined tendon" located with a gauze (Küttner) dissector. If the transversalis fascia appears strong enough, it alone is used for the upper leaf of the repair. If it is not adequate, one must go higher and include the internal oblique aponeurosis. In no instance, however, should "red" muscle be used. The transversalis fascia, and often the "conjoined tendon" therefore, forms the upper leaf of the repair, while Cooper's ligament is the lower leaf. As stated previously, Cooper's ligament is an extremely tough thickening of the periosteal structures on the anterosuperior surface of the anterior ramus of the pubis.

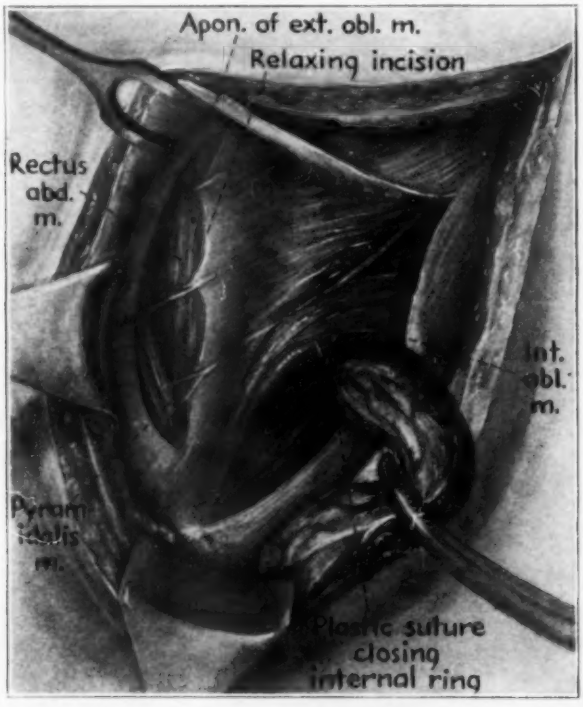

Fig. 7.—Cooper's ligament herniorrhaphy—plastic closure of internal ring and relaxation of internal oblique muscle. The internal ring has been closed by a plastic stitch in the transversalis fascia while the internal oblique has been relaxed close to its junction with the external oblique aponeurosis to form the linea alba. An attempt is made to spare the nerves and accompanying blood vessels. (From *S. Clin. North America*, October 1943.)

During the first year or so that this repair was used, Cooper's ligament was visualized by breaking down Hesselbach's triangle. Then for a year or so the sutures were applied blindly, Hesselbach's triangle being left intact. Recently, however, there has been a return to the principle of direct visualization of Cooper's ligament, it being decided that it is easier and safer to apply the sutures when there is direct vision.

McVay [32] uses the method of direct visualization. After separation of the fascia over the anterior ramus, Cooper's ligament is exposed. The left index finger is placed on the anterior ramus of the pubis near the spine and moved laterally along the crest until the femoral vessels are reached. This is usually about 4 cm. lateral to the spine of the pubis. Since the finger is held in close contact with the bone, the vessels being kept lateral, and the first stitch is placed medial to the finger there is little danger of damaging the vessels. The first stitch is thus usually 3 to 4 cm. lateral to the pubic spine. Therefore, since the upper leaf is to be grabbed with the suture first, the needle goes through the trans-

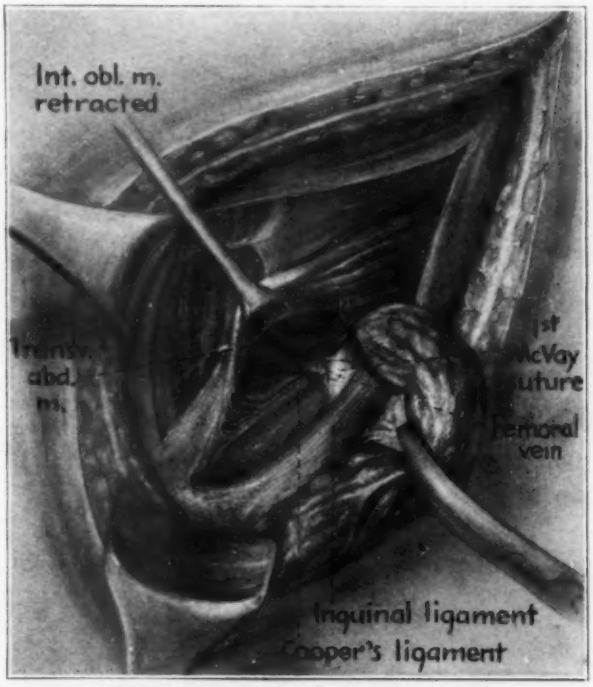

Fig. 8.—Cooper's ligament herniorrhaphy—first Cooper's ligament suture. This suture joins the transversalis fascia and adjoining "conjoined tendon" above to Cooper's ligament below. The most lateral suture is placed first and is separated from the femoral vessels, which lie laterally, by the tip of the left index finger of the operator, the finger being held tightly in contact with the pubic bone underlying Cooper's ligament.

versalis fascia a corresponding distance of about 4 cm. from the pubic spine and then through the thick Cooper ligament on the upper border of the pubic ramus. The stitch is then tied as shown in figure 8 and the intervening gap between this point and the pubic spine is closed with three or four similar sutures, as shown in figure 9. The most medial sutures usually go through Gimbernat's (lacunar) ligament as

32. McVay: Personal communication to the authors, Feb. 21, 1947.

well as Cooper's. It is important that the most lateral suture be placed first, as otherwise it is more difficult to protect the vein. The sutures into Cooper's ligament are of double heavy silk and are applied with a small round curved Mayo needle, which is best held with a Bland or a Jones needle holder. The double strands are made into a triple knot, and then the individual strands are separated and tied in pairs (this is called "braiding"). The relatively large amount of silk used has seldom caused trouble. In certain cases, because of the prominence of Rosenmüller's gland (a lymph gland lying over Cooper's ligament about 2 cm. medial to the femoral vessels) or because of doubt as to the position

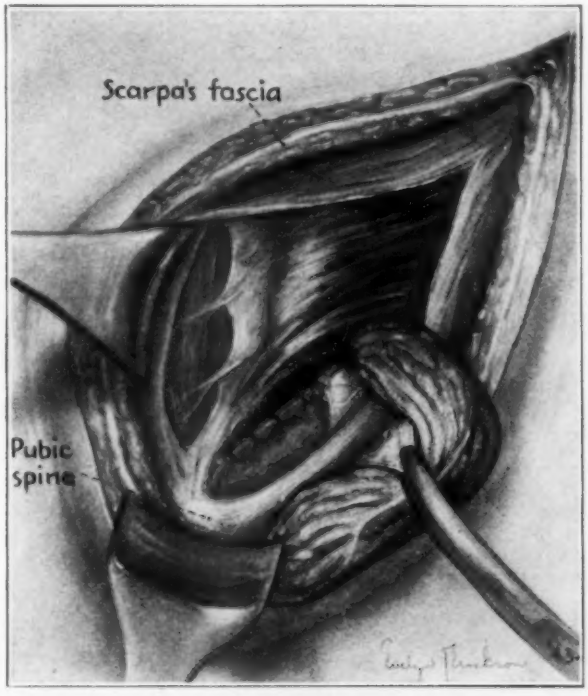

Fig. 9.—Cooper's ligament herniorrhaphy—completion of Cooper's ligament sutures. Usually four or five such sutures are introduced, the most medial of which also pass through the lacunar (Gimbernat's) ligament (modified by H. W. Symmes; original drawing by Evelyn Erickson).

of the vein the sutures are carried out only half way or more from the pubic spine to the femoral vessels. This is termed a partial operation or a "partial McVay," and in the 230 most recent cases it has only been done twice (0.9 per cent). Babcock [33] advised one such medial

33. Babcock, W. W.: The Ideal in Herniorrhaphy: A New Method Efficient for Direct and Indirect Inguinal Hernia, Surg., Gynec. & Obst. **45**:534-540 (Oct.) 1927.

suture in conjunction with his operation for direct hernia. The space between the most lateral stitch in Cooper's ligament and the plastic suture on the internal ring often seems to be a possible weak spot to those doing the operations for the first time. Actually this is not so, because the arched internal oblique muscle will tend to close this defect on contraction. Any attempt to tighten it by suturing the internal oblique or "conjoined tendon" to Poupart's ligament defeats the purpose of the operation. Such a step interferes with the sphincter-like action of the internal ring and tends to pull the transversalis fascia away from Cooper's ligament.

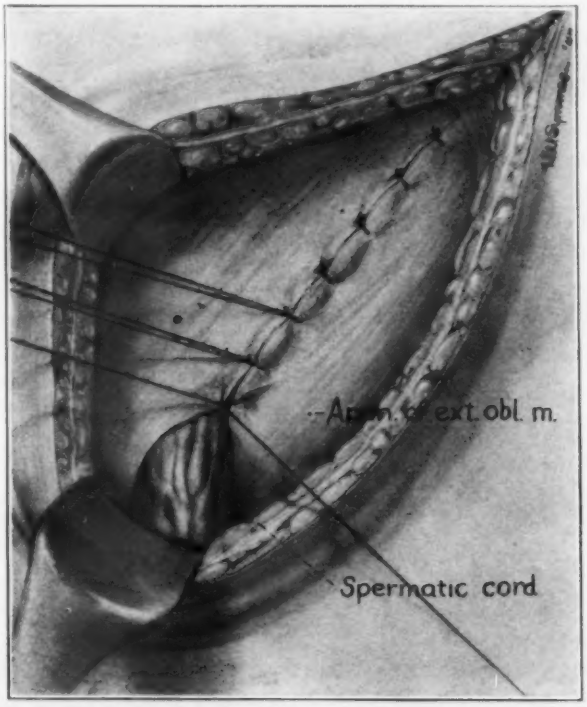

Fig. 10.—Cooper's ligament herniorrhaphy—superficial closure. The cord is dropped into the dead space and the external oblique aponeurosis (as in the figure), Scarpa's fascia and the skin are closed with interrupted silk sutures in layers over the cord.

8. *Closure of the External Oblique Aponeurosis.*—In the first third of this series of cases the external oblique aponeurosis was closed beneath the cord after the manner of the original Halsted-I procedure in the majority (61 per cent). In the more recent two thirds of the series, however, it has most often been closed over the cord, the latter being dropped into the dead space left by the closure. Thus more recently the usual closure of the external oblique has been done in a typical

Bassini manner (97 per cent). We call these two variations of the procedure the Halsted-I-Lotheissen and the Bassini-Lotheissen. There has been one recurrence when the former method was used and two when the latter was used. In both procedures the external oblique is closed with interrupted fine or medium silk sutures, little if any imbrication being used.

9. *Closure of Scarpa's Fascia.*—Closure of Scarpa's fascia with small bites of the suture seems more sound anatomically and leaves less silk than does suture of the fat with large bites taken at random. The sutures are preferably placed so that the knot will be down.

10. *Closure of the Skin.*—Interrupted mattress sutures of silk are advisable for this step. The proper closure of the lower third of the wound inside the hair line is of especial importance.

TABLE 1.—*Sex of Patients*

	Number of Patients	Percentage
Male	286	97
Female	8	3
Total	294	100

TABLE 2.—*Side on Which Hernia Occurred*

	Number of Patients	Percentage
Right	118	40
Left	102	35
Bilateral	74	25
Total	294	100

MATERIAL

With the use of the Cooper ligament technic as described, three hundred and sixty-seven hernias have been repaired during the past seven years. The operations were done by one of us (H. N. H.) and by fourteen members of the resident staff under his direction.

Sex.—The predominance of males in this series (97 per cent, as shown in table 1) reflects the usual sex difference, which is much exaggerated by the industrial occupations of the clientele.

Side.—The right side was operated on most often, as shown in table 2, while in 74 instances a bilateral repair was performed. The table refers to this type of operation only; in several instances, especially early in the series, procedures were done on the other side which are not listed. In every such instance the operation through Cooper's ligament was performed on the side with the largest hernia. For technical reasons a

Lotheissen operation on the left side is more difficult for a right-handed surgeon than a similar operation on the right side.

Classification.—As seen in table 3, the incidence of the various types of hernia represented is approximately that found in an average series except that there were a large number of patients with direct inguinal weakness and also a large number with recurrent hernia (usually following operations done elsewhere). The high incidence of direct hernias is partly due to the fact that early in the series, when the procedure was still viewed somewhat as an experiment, it was used especially for direct hernias. Later, however, it was used in all cases, and during one five year period one of us (H. N. H.) used no other type of repair. Another reason for the large number of direct hernias is that with routine inspection of Hesselbach's triangle with the gloved index finger from inside we detected a large number of direct weaknesses that would otherwise go unnoticed. The large number of operations for recurrent hernia

TABLE 3.—*Types of Hernia Represented*

Classification	Number of Hernias	Percentage
Simple indirect	169	45
Simple direct	85	23
Indirect and direct (saddle-bag)	56	15
Femoral and indirect	8	2
Femoral and saddle-bag	3	1
Sliding	3	1
Incarcerated	6	2
Recurrent indirect	20	5.2
Recurrent direct	21	5.2
Recurrent femoral	1	0.3
Recurrent saddle-bag	1	0.3
Total *	373	100

* Including several duplications.

(forty-one, in seven of which there was reenforcement with strips of free fascia lata) represents the unusually high incidence of 11 per cent in the entire series of three hundred and sixty-seven operations. Many of the patients had been operated on more than once before. In 1 case our operation was the fifth done for a single femoral hernia. None of these hernias previously operated on have recurred after our operations.

Follow-Up Studies.—Completion of the follow-up studies proved difficult because of wartime migrations and employment difficulties As seen in table 4, slightly more than one third of the patients have been followed for more than two years. Many other patients reported excellent results by letter or were even seen afterward for other complaints by other physicians. However, for the purposes of this study the only follow-up observations included are those involving actual examination of the groin by a physician. Furthermore, if the 28 patients operated on less than two years before this paper was written and hence not eligible for inclusion because of incomplete follow-up are excluded, the percentage followed for over two years is raised from 35 to 39.

There have been three recurrences, as described in the following case reports.

CASE 1.—V. M., a man aged 46 years, had a bilateral indirect inguinal hernia repaired by the original Halsted-I-Lotheissen method on Nov. 26, 1940. The right side was repaired by an assistant resident and the left by one of us (H. N. H.). A recurrence of the hernia on the right side was discovered in April 1942 (seventeen months after operation), and reoperation was performed on the twenty-eighth day of that month. At operation an indirect sac 2 cm. in diameter was found, possibly because the internal ring had not been closed snugly enough.

CASE 2.—Repair of an indirect inguinal hernia on the right side was done by one of us (H. N. H.) on Sept. 29, 1942. Soon afterward the patient joined the army, and in May 1945 (thirty-two months after operation) while jumping from a landing craft with a full pack in the Southwest Pacific he noted a pain in the right groin. Two months later a hernia recurring "at the lower angle of the wound" (a direct recurrence?) was repaired by an army surgeon.

TABLE 4.—*Period of Follow-up* *

	Number of Patients	Number of Hernias
Less than twelve months	164	197
Twelve to twenty-four months	27	39
Two years	18	24
Three years	26	34
Four years	16	18
Five years	34	44
Six years	9	11
Total	294	367
Number followed for over 2 years	103	131
Per cent followed for over 2 years	35	36
Recurrence rate:		
Per cent of cases followed for over 2 years	2.9	2.3
Per cent of total cases	1.0	0.8

* There were three recurrences, which occurred seventeen, eighteen and thirty-two months postoperatively; two were indirect recurrences, and one was a direct recurrence.

CASE 3.—A Bassini-Lotheissen operation by an assistant resident physician for an indirect inguinal hernia on the left side was done on Dec. 1, 1942. A recurrence was noted eighteen months later, and repair was carried out soon afterward. At the second operation there was no direct weakness, but a large indirect sac was present which according to the operator showed "no evidence of the indirect sac ever having been ligated."

There was 1 death in the hospital, described in the following report.

CASE 4.—D. M. was a Negro aged 51 years. The weight was 276 pounds (125 Kg.) and the height 71 inches (180 cm.). There was an inguinal hernia on the left side extending over halfway from the groin to the knee. This was repaired by an original Halsted-I-Lotheissen procedure on June 3, 1944, by one of us (H. N. H.). The patient died on the twelfth postoperative day of massive pulmonary embolism, a diagnosis which was proved at necropsy. (At the time of death the wound was found to be infected.)

It is of interest that in the 2 patients operated on by assistant residents the recurrences were indirect while in the other patient (operated on by H. N. H.) the recurrence was direct.

The recurrence rate was 2.3 per cent for the cases followed for over two years and 0.8 per cent for the entire group of cases. In the group of 203 of these cases handled by one of us (H. N. H.) there was one recurrence, giving a rate of 0.5 per cent. When this figure is corrected by the exclusion of the thirty-three operations done during the past two years (after which, of necessity, there was not a two year follow-up) the recurrence rate for the entire series is even less.

In the group of patients followed in whom there was no recurrence the incidence of pain and other subjective symptoms was roughly comparable to that in patients treated by other technics.

COMMENT

Anderson,[34] in discussing the causes of failure in repair of inguinal hernia, stated:

> It is obvious that when the transversalis fascia is attached to Poupart's instead of Cooper's ligament an undesirable pocket is left. That is, the normal insertion and attachment of the transversus aponeurosis and transversalis fascia in this region is into the rectus sheath medially, then into the pubic bone and outward laterally into the ilio-pectineal line (Cooper's ligament). Since this is its normal insertion, this is where it should be attached when carrying out a repair. If, as has been commonly done, it is sewn to Poupart's ligament, a peritoneal trough-like pouch tends to form, the potential beginning of a recurrent hernia.

Then the Canadian writer goes on to say:

> In the case of hernias and tires, there is a first line of defense, the transversalis fascia and the inner tube, respectively. We do not fasten the edge of the hole in the inner tube to the outer casing; no more should we fasten the edge of the transversalis fascia to the outer casing, the external oblique (Poupart's ligament), but rather to its own structure and insertion—Cooper's ligament.

The suture of the transversalis fascia or of the "conjoined tendon" to Cooper's ligament is, according to Brunkow,[35] "likened to pulling the curtain clear to the base of the window instead of only halfway for an effective blackout." The same procedure can also be compared with tucking the sheets in at the foot of the bed so that the toes of a tall person will not protrude.

Our studies bear out these theoretic advantages of the procedure. We do not believe that we have evidence that the Cooper ligament technic is infallible, or that it is better than other reputable methods or that it should be immediately adopted by all other operators. We do

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34. Anderson, R.: Failures in Inguinal Hernia, Canad. M. A. J. **49**:392-396 (Nov.) 1943.

35. Brunkow, B. H.: Surgical Considerations of the Inguinal Triangles, Am. J. Surg. **59**:594-597 (March) 1943.

believe, however, that in our hands it has given good results and that we are justified in the continuation of its use.

As to its scope at the present time, the technic seems to us to be the preferable one for the following types of hernia in the groin: (1) recurrent hernia, (2) femoral hernia, (3) direct hernia and (4) indirect hernia in older patients in whom Hesselbach's triangle shows signs of weakness. The method would, on the other hand, seem to be superfluous for young patients with uncomplicated congenital indirect inguinal hernias.

SUMMARY AND CONCLUSIONS

A hernial repair based on the anatomic studies of McVay and Anson, who postulated that the transversalis and internal oblique fibers normally attach themselves not to Poupart's ligament but rather to Cooper's ligament, has been utilized which attempts to restore the normal attachments to the latter. In this operation, first advocated by Lotheissen for the repair of femoral hernia, no fascial layer is sutured to Poupart's ligament.

An identical procedure is used for all the main types of hernia of the groin—indirect inguinal, direct inguinal and femoral. The fact that only one technic need be learned may be another advantage of this method.

This technic has been used in the repair of three hundred and sixty-seven hernias of the groin of several types in 294 patients during a seven year period. Follow-up studies indicate that the results as well as the theoretic advantages justify the procedure. Of one hundred and thirty-one hernias in patients followed for two years or more, three have recurred (2.3 per cent), while for the entire series of cases the known recurrence rate is 0.8 per cent.

DISCUSSION

DR. CHESTER MCVAY: My own comment on the operative procedure should wait until I have my own series which is now almost complete. I thought this morning that I would simply show three slides to reemphasize something which Dr. Harkins has already said.

(Slide) This is a view of the inguinal region with the external oblique muscle open, showing Hesselbach's triangle. These are the fibers of the transversalis going not to the inguinal ligament but to Cooper's ligament.

(Slide) The next slide is picked from another series showing the inguinal ligament completely away and the fibrous insertion passing over to the midline and showing the spermatic vessels down to Cooper's ligament.

(Slide) Dr. Harkins said that this repair is used for all types of hernia. This oblique view of the inguinal region will demonstrate why it is applicable. The defect in a large indirect, direct or femoral hernia is a defect in the same layer. The problems are the same. For instance, an indirect hernia, as it enlarges, enlarges medialward, and in extremely large ones it compromises this area. A femoral hernia enlarges medially, and it compromises this area. A direct hernia is

definitely through this area. Except in the case of a very small indirect hernia, resuturing of the stronger layer above to Cooper's ligament reestablishes the normal anatomy. The steps outlined by Dr. Harkins I agree with perfectly.

Dr. Roland F. Mueller, Lincoln, Neb.: I have been interested in the results obtained by Dr. Harkins with this procedure. Of 149 consecutive cases of hernia in which I have operated and which I have followed for the past six years, 15 were cases of femoral hernia. This is an incidence of 10 per cent, as compared with the usual incidence of 5 to 6 per cent given in the literature for femoral hernias. In the 149 cases, the McVay technic, using Cooper's ligament, was employed in 42. There were five recurrences among the 149, and two of these occurred among the 42 cases in which the Cooper ligament repair was used. The 2 patients were among the earlier ones operated on by this method, and I feel that with additional experience there will be fewer recurrences. It is curious to note that some of these patients do not know that they have a recurrence because it is so trivial and symptomless. One cannot always rely on correspondence as a method of follow-up. In fact, two of the above five recurrences were so trivial that the patients did not feel that they had a recurrence.

In the surgical repair of femoral hernia I feel that they should all be approached by this route—through the inguinal canal. There were no recurrences among the femoral hernias repaired, all five being recurrences of inguinal hernia.

The exposure of Cooper's ligament is not particularly difficult. Frequently one may be surprised by the fast dropping away of Cooper's ligament as one exposes it posteriorly and laterally, as compared with the course of the inguinal ligament. The one drawback to the use of Cooper's ligament as an anchor is the area of potential weakness remaining superior and lateral to the posterior suture placed in the ligament.

EFFECT OF DISTENTION OF THE BILIARY TRACT ON THE ELECTROCARDIOGRAM

Experimental Study

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AND

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DURHAM, N. C.

THE COEXISTENCE of disease of the biliary tract and disease of the heart is well known. Willius and Brown [1] analyzed eighty-six unselected consecutive necropsies on patients with proved coronary sclerosis. Chronic cholecystitis with or without cholelithiasis was present in 26 per cent. Laird [2] found cardiac lesions in 77 per cent of a series of 65 patients with disease of the gallbladder. In 109 cases of cholecystitis Schwartz and Herman [3] found evidence of cardiac disease in 63 per cent. An incidence of only 41 per cent was found in another 109 medical patients without clinically recognized disease of the biliary tract or cardiac disease.

These and other reports show that there is an increased incidence of cardiac disorders in patients with disease of the biliary tract. There are many physiopathologic factors common to the two diseases, such as age, disturbed metabolism, obesity, diet and infection.

Surgical intervention for cholecystitis, cholelithiasis or choledocholithiasis has frequently resulted in improvement of an associated cardiac condition. This has been manifested by relief from angina, recovery from decompensation and improvement or return to normal of the electrocardiogram (Fitz-Hugh and Wolferth,[4] Wolferth,[5] Ravdin, Royster

From the departments of surgery and medicine, Duke University Medical School and Hospital.

1. Willius, F. A., and Brown, G. E.: Coronary Sclerosis: An Analysis of Eighty-Six Necropsies, Am. J. M. Sc. **168**:165, 1924.

2. Laird, S. M.: The State of the Heart in Gall-Bladder Disease: A Personal Investigation, Brit. M. J. **1**:884, 1938.

3. Schwartz, M., and Herman, A.: The Association of Cholecystitis with Cardiac Affections: A Study Based on One Hundred and Nine Cases, Ann. Int. Med. **4**:783, 1931.

4. Fitz-Hugh, T., Jr., and Wolferth, C. C.: Cardiac Improvement Following Gall Bladder Surgery, Ann. Surg. **101**:478, 1935.

5. Wolferth, C. C.: Relationship between Biliary Tract Disease and Heart Disease, J. Mt. Sinai Hosp. **8**:1121, 1942.

and Sanders,[6] Moschcowitz,[7] Clarke,[8] Weiss and Hamilton,[9] Laird,[2] Schwartz and Herman,[5] Straus and Hamburger[10] and McArthur and Wakefield.[11]).

Attacks of pain in the gallbladder or of colic may simulate attacks of angina pectoris or coronary occlusion since the pain is occasionally referred to a similar segmental distribution. The pain in disease of the gallbladder, however, is usually referred along the seventh and eighth thoracic spinal segments and is commonly right sided, whereas the pain in angina pectoris is commonly left sided and referred along the fifth to the eighth cervical spinal segments and the first to the fourth thoracic spinal segments. In angina pectoris the pain is frequently referred down the left arm and can be brought on by effort and relieved with nitroglycerin.

The electrocardiogram may not always aid in a correct diagnosis since intra-abdominal diseases such as cholecystitis, pancreatitis or perforated peptic ulcer have been reported to cause electrocardiographic alterations (Murphy and Livezeg,[12] Gubner,[13] Scherf and Klotz[14] and Gottesman, Casten and Beller[15]).

The abnormalities noted in these conditions are changes in the T waves in significant leads, slurring and notching of the QRS complexes and elevation or depression of the S-T segments.

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6. Ravdin, I. S.; Royster, H. P., and Sanders, G. B.: Reflexes Originating in the Common Duct Giving Rise to Pain Simulating Angina Pectoris, Ann. Surg. **115**:1055, 1942.

7. Moschcowitz, E.: The Electrocardiogram in Uncomplicated Disease of the Gall Bladder and the Changes Induced by Operation, J. Mt. Sinai Hosp. **10**:632, 1944.

8. Clarke, W. E.: Electrocardiographic Changes in Active Duodenal and Gall Bladder Disease, Am. Heart J. **29**:628, 1945.

9. Weiss, M. M., and Hamilton, J. E.: The Effect of Gall Bladder Disease on the Electrocardiogram, Surgery **6**:893, 1939.

10. Straus, D. C., and Hamburger, W. W.: The Significance of Cardiac Irregularities in Reference to Operability of Cholelithiasis, Cholecystitis and Duodenal Ulcer, J.A.M.A. **82**:706 (March 1) 1924.

11. McArthur, S. W., and Wakefield, H.: Observations on the Human Electrocardiogram During Experimental Distention of the Gall Bladder, J. Lab. & Clin. Med. **30**:349, 1945.

12. Murphy, F. D., and Livezeg, M. M.: Electrocardiographic Changes Simulating Those of Acute Myocardial Infarction in a Case of Perforated Gastric Ulcer, Am. Heart J. **28**:533, 1944.

13. Gubner, R. S.: Electrocardiographic Changes in Abdominal Disease, J.A.M.A. **124**:122 (Jan. 8) 1944.

14. Scherf, D., and Klotz, S. D.: Electrocardiographic Changes After Acute Loss of Blood, Ann. Int. Med. **20**:438, 1944.

15. Gottesman, J.; Casten, D., and Beller, A. J.: Changes in the Electrocardiogram Induced by Acute Pancreatitis: A Clinical and Experimental Study, J.A.M.A. **123**:892 (Dec. 4) 1943.

When these findings are present, a correct diagnosis is imperative, since operation on a patient with coronary occlusion should be avoided. Also, an incorrect diagnosis of coronary insufficiency or coronary occlusion in a patient with disease of the biliary tract may result in making a cardiac invalid of a patient who would otherwise be relieved by appropriate surgical intervention. The correct diagnosis can usually be made by adequate elicitation of the patient's history, physical examination and correct roentgenologic and electrocardiographic interpretation.

There appears to be some confusion in the literature regarding the relationship of disease of the biliary tract and cardiac disease. It seems reasonable to us that patients who have disease of the biliary tract with an abnormal electrocardiogram should have in association coronary artery and myocardial disease.

A series of experiments were carried out to study the relationship of disease of the biliary tract and cardiac disease. These consisted of electrocardiographic studies of the effect of distention of the biliary tract in two groups of animals. The first group, with normal hearts, served as controls. The second group had experimentally produced lesions of the coronary artery.

EXPERIMENTAL METHODS

In all experiments adult male and female dogs were used. Light anesthesia was produced with the intravenous injection of chloralose, the dose employed being approximately 0.1 Gm. per kilogram of body weight. The choice of anesthetic is important, since electrocardiographic changes and changes in the blood pressure may occur with the administration of ether, cyclopropane and the barbiturates (Schafer, Underwood, and Gaynor [16] and Gruber [17]).

A series of 5 dogs without cardiac lesions was used as a control group. Electrocardiograms were obtained before the induction of anesthesia with the animal resting on its back. Chloralose was then administered intravenously, and an electrocardiogram was taken with the animal under anesthesia. Through an incision in the right upper area of the abdomen the common bile duct was ligated with two braided silk ligatures close to the duodenum. Care was taken to ligate as low as possible and to ligate only the duct in order that the nerve plexuses would be undisturbed. A cannula was inserted in the fundus of the gallbladder and held in place with a purse-string suture and ligature. A special manometer with a side tube for the injection of isotonic solution of sodium chloride was attached to the cannula. The left common carotid artery was cannulated and prepared for kymographic tracing of the blood pressure.

Respirations were recorded on the kymograph with the use of a chest tambour. Electrocardiographic changes, blood pressure and respirations were recorded at

16. Schafer, G. D.; Underwood, F. J., and Gaynor, E. P.; The Action of Amytal in Impairing Vagus Cardiac Inhibitory Effects and of Ether in Increasing the Respiratory Rate After Its Depression by Amytal, Am. J. Physiol. **91**:461, 1929.

17. Gruber, C. M.: The Barbiturates and the Thiobarbiturates: Some Differences in Their Actions When Administered to Human Beings and to Experimental Animals, J.A.M.A. **117**:1147 (Oct. 4) 1941.

intervals with varying degrees of pressure (5 to 560 cm. of water) in the biliary tract. At the end of the experiments the animals were subjected to autopsy.

Two additional animals without cardiac lesions were subjected only to ligation of the common duct. Serial electrocardiograms were taken at intervals for periods of nineteen and twenty-two days to study the effect of chronic obstruction and jaundice.

In another series of 10 animals cardiac lesions were produced by injection of a sclerosing solution of invert sugar about the left main descending coronary artery or by ligation of various branches of the left descending coronary artery and the circumflex arteries.

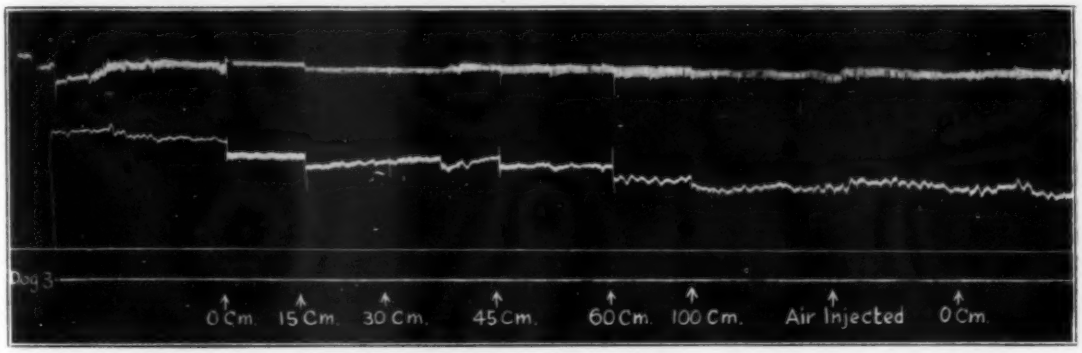

Fig. 1.—Kymogram on dog 3. Blood pressure and respirations with varying degrees of biliary pressure. Note the fall in blood pressure and respiratory changes with distention.

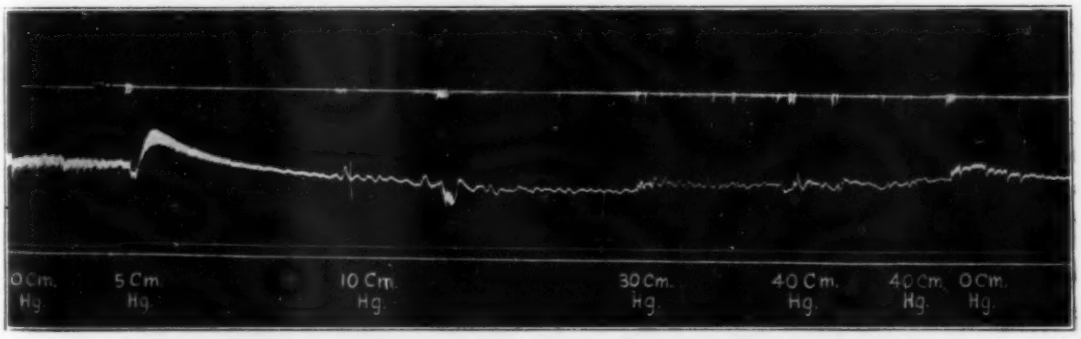

Fig. 2.—Kymogram on dog C-2 seventeen days after ligation of the coronary artery. Note the blood pressure and the respirations with varying degrees of biliary pressure.

Of this group, 3 animals died with ventricular fibrillation; 1 died in six hours and 2 in eight hours. Another animal died on the fifth postoperative day after disruption of the thoracotomy wound. Atropine and quinidine were employed intravenously in the 6 remaining animals to prevent ventricular fibrillation. In this group coronary lesions were produced by ligation in 5 and by injection in 1.

Intravenously administered chloralose with endotracheal positive air pressure was employed for the operative procedure. The heart was approached through

a thoracotomy incision made on the left anterior side in the fifth interspace. Ligation with silk or periarterial injection of the coronary vessels was carried out.

Electrocardiograms were taken before and after anesthesia, with the chest open before and after ligation or injection of the coronary artery and at varying intervals thereafter for twelve to seventeen days until the biliary tract was distended.

In 5 of the animals distention of the biliary tract was performed in the same manner as in the control group. Serial electrocardiographic tracings, blood pressure and respirations were recorded. In another animal ligation of the common bile duct was carried out after ligation of the coronary artery. The ligature around the common duct cut through, with reopening, which necessitated religation

TABLE 1.—*Results of Distention of the Biliary Tract in Control Dogs*

	Biliary Tract Pressure, Cm. H_2O	Blood Pressure, Mm. Hg	Cardiac Rate	Respirations with Distention	Electrocardiogram
Dog 1					
Initial	5	200	150	Slower and deeper	No change except
After distention	100	140	155	with inspiratory	in rate
Final	0	150	176	difficulty	
Dog 2					
Initial	2.5	180	220	Slower and deeper	No change with
After distention	300	150	228	with inspiratory	distention
Final	0	160	215	difficulty	
Dog 3					
Initial	5	140	134	Slower and deeper	No change
After distention	100	98	140	with inspiratory	
Final	0	100	114	difficulty	
Dog 4					
Initial	2.5	160	115	Slower and deeper	No change except
After distention	340	60	220	with inspiratory	for increase in the
Final	0	120	220	difficulty	cardiac rate
Dog 5					
Initial	0	170	84	Slower and deeper	There was flattening
After distention	680	94	165	with inspiratory	of the waves in all
Final	0	100	202	difficulty	leads but no deviation of the RS-T segment or junction

four weeks later. Serial electrocardiograms were taken at intervals throughout this period. The animal was subjected to autopsy eleven days after the second ligation.

RESULTS

The results in the control group are summarized in table 1. In the 5 dogs subjected to acute biliary distention there were no significant changes in the electrocardiogram following distention other than variations in the cardiac rate (figs. 3 and 4). In the 2 dogs in which chronic distention of the biliary tract and jaundice were produced by ligation of the common bile duct there were no significant electrocardiographic changes at the end of nineteen and twenty-two days (Buch-

binder [18]). The pressures in the biliary tract were 30 and 45 cm. of water. No blood pressure recordings or respiratory tracings were made.

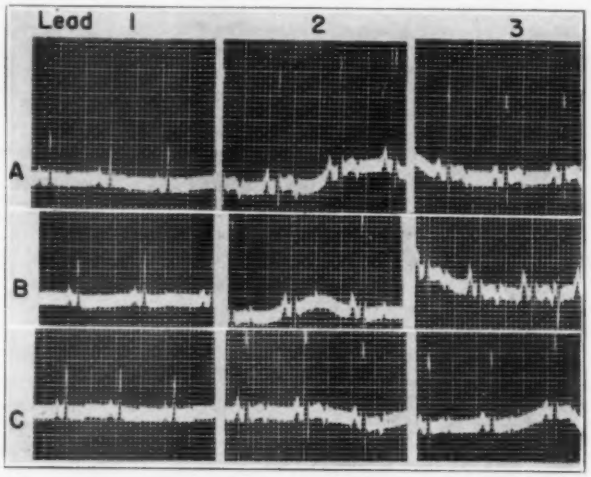

Fig. 3.—Electrocardiogram on dog 3 (control). *A*, under anesthesia. *B*, biliary distention with a pressure of 100 cm. of water. *C*, release of biliary pressure to zero.

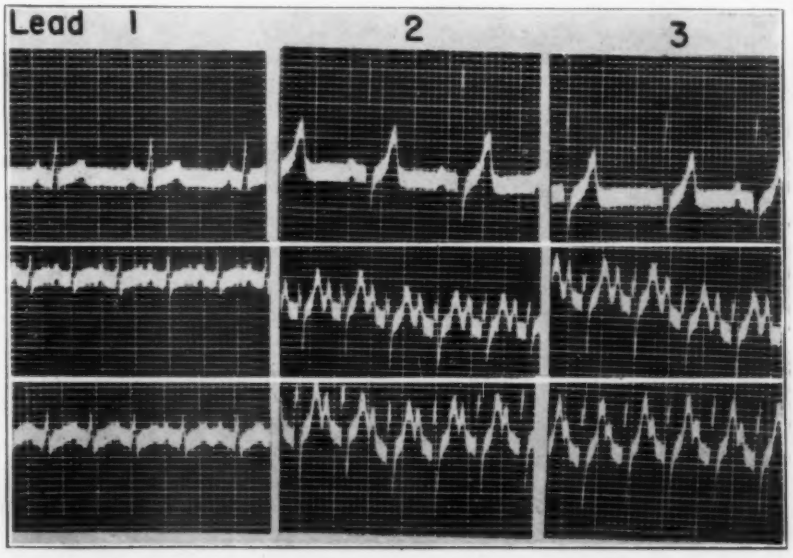

Fig. 4.—Electrocardiogram on dog 4 (control). *A*, under anesthesia. *B*, biliary distention with a pressure of 340 cm. of water. *C*, release of biliary pressure to zero. The cardiac rate was increased with distention, but there was no deviation of the RS-T segment.

18. Buchbinder, W. C.: The Electrocardiogram in Experimental Obstructive Jaundice, Proc. Soc. Exper. Biol. & Med. **27**:371, 1930.

The results of distention of the biliary tract in the dogs with lesions of the coronary artery are summarized in table 2. In dog C-1

TABLE 2.—*Results of Distention of the Biliary Tract in Dogs with Lesions of the Coronary Artery*

	Biliary Tract Pressure, Cm. H_2O	Blood Pressure, Mm. Hg	Cardiac Rate	Respirations with Distention	Electrocardiogram
Dog C-1—Thirteen Days after Injection of the Left Anterior Descending Coronary Artery. (Infarction of the Anterior Wall, Left Ventricle)					
Initial	2.5	170	80	Inspiratory distress	No electrocardiographic
After distention	400	110	81	slower and deeper	changes with distention
Final	0	110	81		
Dog C-2—Seventeen Days after Ligation of the Middle Branch of the Left Descending Coronary Artery (Infarction of the Posterior Lateral Wall, Left Ventricle)					
Initial	5	130	110	Inspiratory distress	With distention of the
After distention	540	96	180	slower and deeper	biliary tract there was
Final	0	130	180		marked sagging of the RS-T segments in leads II and III which did not return to the isoelectric line after distention was released
Dog C-3—Seventeen Days after Ligation of the Main Circumflex Branch of the Left Coronary Artery (Infarction of the Posterior Lateral Wall, Left Ventricle)					
Initial	5	128	140	Inspiratory distress	After distention the RS-T
After distention	540	70	65	slower and deeper	junction became elevated
Final	0	70	141		in all leads, with a notable increase in the height of the T waves
Dog C-4—Twelve Days after Ligation of the First and Second Circumflex Branches of the Coronary Artery (Infarction of the Posterior Wall, Left Ventricle)					
Initial	5	146	205	Inspiratory distress	After distention there
After distention	540	110	180	slower and deeper	was elevation of the
Final	0	140	200		RS-T junction with increase in the height of the T waves; after release of pressure the record returned to normal; crushing the leg did not change the record
Dog C-5—Twelve Days after Ligation of the Anterior and Middle Branches of the Left Descending Coronary Artery (Apical Infarction)					
Initial	5	150	90	Inspiratory distress	After distention there
After distention	540	130	150	slower and deeper	was elevation of the
Final	0	150	184		RS-T junction with increase in amplitude of the T waves in all leads, which returned to normal after release of the pressure

there were no significant changes in the RS-T junction or segment. In dog C-2 there was considerable depression of the RS-T segment in leads II and III with distention of the biliary tract. After release of

the pressure, the RS-T depression became less marked, but it did not return completely to the isoelectric line (fig. 5). These changes resemble the electrocardiographic findings in coronary insufficiency with myocardial ischemia in man. In dogs C-3, C-4 and C-5 there were pronounced elevation of the RS-T junction and an increase in amplitude of the T waves. After release of pressure in the biliary tract, the records were the same as those taken before distention (figs. 6, 7 and 8). In dog C-4 there was no change in the record after the leg was crushed. In dog C-5 administration of 1 mg. of atropine did not prevent the changes from taking place. After the testicle was crushed there was some change in the RS-T junction, but it was definitely less than that

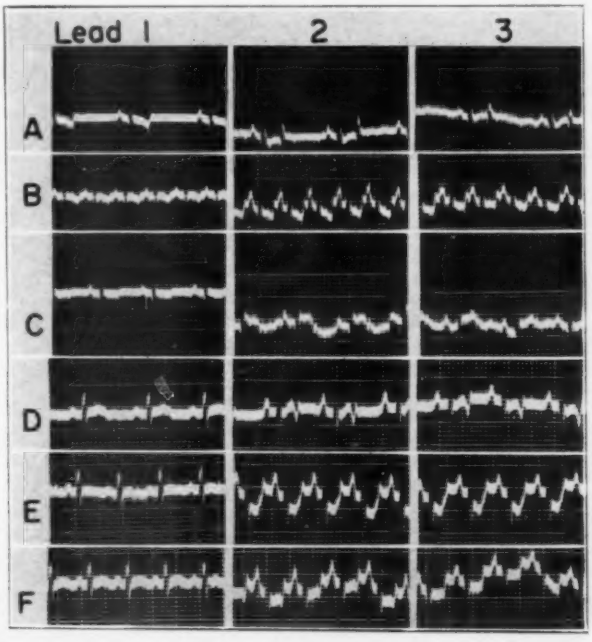

Fig. 5.—Electrocardiogram on dog C-2 with coronary lesion. *A*, control. *B*, one hour after ligation of the middle branch of the left descending coronary artery. *C*, forty-eight hours after ligation of the coronary artery. *D*, under anesthesia seventeen days after ligation of the coronary artery. *E*, biliary distention with a pressure of 540 cm. of water. *F*, release of biliary pressure to zero. The marked sagging of the RS-T segments in leads II and III with distention of the gallbladder are suggestive of coronary insufficiency with myocardial ischemia in man.

produced by biliary distention. In 1 dog, C-6, with chronic obstruction and distention the electrocardiogram showed no change. The biliary pressure was 45 cm. of water.

The respiratory changes were similar to those described by Schrager and Ivy.[19] There was a decrease in rate with inspiratory inhibition.

19. Schrager, V. L., and Ivy, A. C.: Symptoms Produced by Distension of Gall Bladder and Biliary Ducts, Surg., Gynec. & Obst. **47**:1, 1928.

In control experiments there were no significant electrocardiographic changes after anesthesia with chloralose. Only minor variations consisting of changes in cardiac rate were noted.

In the control group pathologic examination of the various organs including the heart, liver and extrahepatic bile passages failed to reveal any abnormalities except in the 2 animals subjected to chronic obstruction. In these only the liver and bile passages showed changes characterized by dilated bile ducts and canaliculi, with an intense

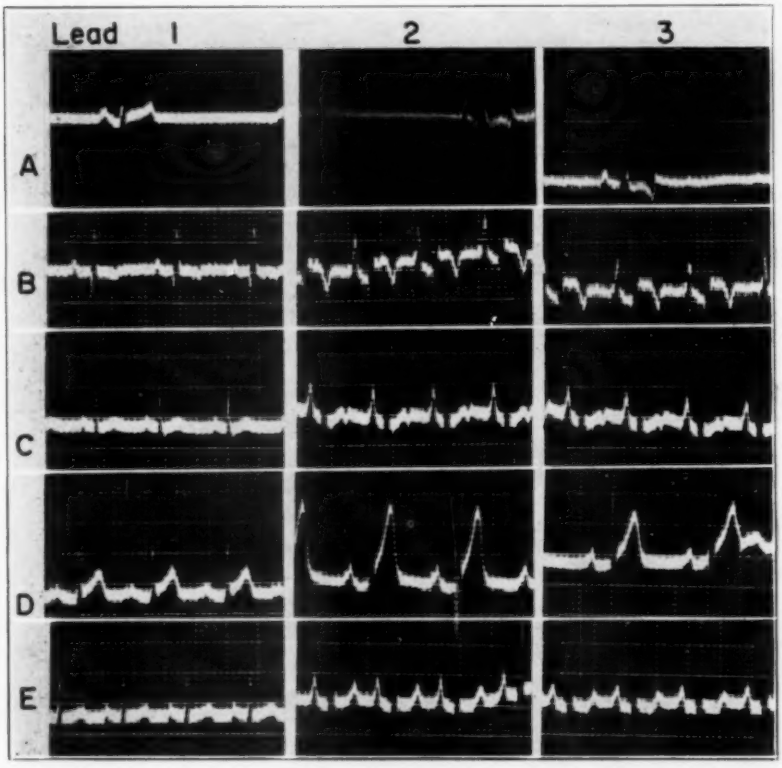

Fig. 6.—Electrocardiogram on dog C-3. *A*, control. *B*, forty-eight hours after ligation of the main circumflex branch of the left coronary artery. *C*, under anesthesia seventeen days after ligation of the coronary artery. *D*, biliary distention with a pressure of 540 cm. of water. Note the increase in amplitude in the T waves and the elevation of the RS-T junction with distention of the gallbladder. *E*, release of biliary pressure to zero.

periportal inflammatory reaction. The hepatic cells showed fatty degeneration with areas of central necrosis. Bile casts were present in many of the dilated ducts.

In the group subjected to coronary lesions, myocardial infarction with healing in various stages was demonstrated. The liver and the

bile passages in the animal with chronic obstruction were not unlike those in the control group.

COMMENT

The electrocardiogram has been studied extensively in normal dogs and in dogs which have had ligation of the coronary artery (Smith [20]). Lalich, Cohen and Walker,[21] in a study of 218 electrocardiograms on 24 normal dogs, found notable variation of the P, Q, S and T waves. There was slight deviation of the RS-T segment, but it seldom exceeded 1 mm. This confirms the previous observations of Barnes and Mann,[22] who

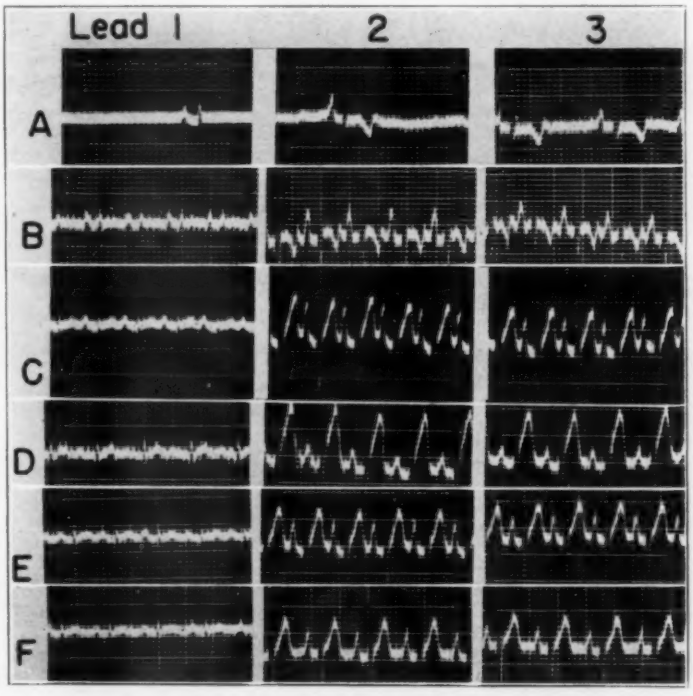

Fig. 7.—Electrocardiogram on dog C-4. *A*, control. *B*, after ligation of the first and second branches of the circumflex coronary artery. *C*, under anesthesia twelve days after ligation of the coronary artery. *D*, biliary distention with a pressure of 540 cm. of water. With distention of the gallbladder there was elevation of the RS-T junction and slight elevation of the T waves. *E*, release of biliary pressure to zero. *F*, unchanged electrocardiogram after crushing of the leg.

20. Smith, F. M.: The Ligation of Coronary Arteries with Electrocardiographic Study, Arch. Int. Med. **22**:8 (July) 1918.

21. Lalich, J.; Cohen, L., and Walker, G.: The Frequency of Electrocardiographic Variations in Normal Unanesthetized Dogs, Am. Heart J. **22**:105, 1941.

22. Barnes, A. R., and Mann, F. C.: Electrocardiographic Changes Following Ligation of the Coronary Arteries of the Dog, Am. Heart J. **7**:477, 1932.

found the T waves to be unstable in the normal dog and altered by manipulation of the heart without interfering with the coronary circulation. They found no significant modification of the RS-T segment. Harris and Hussey [23] found decided variability of the T waves in a study of 50 dogs, but in only 1 was there any deviation of the RS-T segment.

It is clear from the work of the aforementioned investigators that electrocardiographic changes in the dog do not parallel those found in man. Barnes and Mann, however, observed that ligation of the

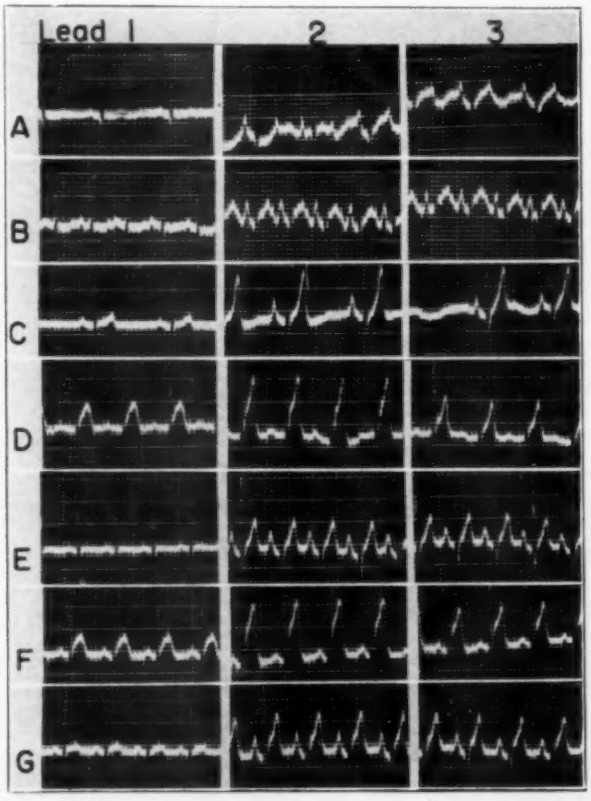

Fig. 8.—Electrocardiogram on dog C-5. *A*, control. *B*, two hours after ligation of the anterior and middle branches of the left descending coronary artery. *C*, under anesthesia twelve days after ligation of the coronary artery. *D*, biliary distention with a pressure of 540 cm. of water. There was elevation of the RS-T junction and increased amplitude of the T waves. *E*, release of the biliary pressure to zero. *F*, distention of the gallbladder ten minutes after 1 mg. of atropine was administered intravenously. The findings are the same as in *D*. *G*, record taken after the testicles were crushed. There were only slight changes in the electrocardiogram resembling those observed with distention of the gallbladder.

23. Harris, B. R., and Hussey, R.: The Electrocardiographic Changes Following Coronary Ligation in Dogs, Am. Heart J. **12**:724, 1936.

coronary arteries in the dog was followed by certain specific changes, namely, deviation of the RS-T segments. These changes were found to be specific for infarction of the anterior or posterior walls of the ventricles. Infarction of the posterior wall of the left ventricle produced elevation of the RS-T segment in lead I and depression of the RS-T segment in lead III. Harris and Hussey found essentially the same changes after ligation of the coronary artery. Gross and Calef,[24] studying the electrocardiographic changes in dogs following sudden occlusion of the left anterior descending coronary artery under various experimental conditions, found elevation of the RS-T segment in lead I and depression in lead III in 90 per cent of the dogs as compared with 12 per cent of a control group. There is, then, general agreement that the T waves in the electrocardiogram on the dog are unstable and that no conclusions are justified from changes in this portion of the electrocardiogram alone. Deviations of significant degree in the RS-T portion are not frequently seen in the electrocardiogram on the normal dog and are consistently seen to occur soon after ligation of the coronary artery. These changes are transient, and the segment usually returns to the isoelectric line within a few days.

In the control group of 5 dogs no significant alteration of the RS-T segment in the electrocardiogram was noted with distention of the biliary tract. In the group of 5 dogs in which there was interference with the coronary circulation there was alteration of the RS-T segment in 4 of the animals during biliary distention. In 1 there was depression in leads II and III, and in 3 there were elevations in all three leads. In only 1 of these (dog C-2) did the pattern resemble the findings of coronary disease in man, but in all 4 the changes were definitely abnormal. Although changes in blood pressure consisting in a drop in systolic pressure occurred both in the control group and in the dogs with coronary lesions, it is not felt that this per se was the cause of the electrocardiographic changes, since there was no significant difference between the changes in the control group and those in the group with coronary lesions. However, the fall in blood pressure may have been sufficient in the dogs with lesions of the coronary artery to cause a decrease in coronary blood flow and thereby result in the changes found in the electrocardiogram.

A discussion of the mechanism of the electrocardiographic changes is beyond the scope of the present paper. A general lowering of the blood pressure and of the viscerocardiac reflexes affecting the cardiac output or the conductive system may account for the electrocardiographic alterations in the animals with a preexisting cardiac lesion. However,

24. Gross, L., and Calef, B.: Electrocardiographic Changes in the Dog Following Sudden Occlusion of the Left Anterior Descending Coronary Branch Under Various Experimental Conditions, Am. Heart J. **14**:677, 1937.

the injection of 1 mg. of atropine intravenously failed to prevent the changes in a single dog. Crushing the leg in 1 of the dogs did not produce any change in the electrocardiogram; however, crushing the testicle of another dog produced changes which resembled those accompanying distention of the biliary tract but which were of lesser degree. There were no significant changes in the blood pressure after the crushing of the testicles or the leg in these 2 animals.

SUMMARY

Distention of the biliary tract in dogs without a preexisting lesion of the coronary artery or the myocardium failed to produce any significant changes in the electrocardiogram.

Distention of the biliary tract in dogs after ligation of one or more of the coronary arteries produced abnormal deviations of the RS-T segments in the electrocardiogram.

TREATMENT OF POSTOPERATIVE SWELLING OF THE ARM FOLLOWING MASTECTOMY

Preliminary Report

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THE subject of postoperative swelling of the upper extremity following mastectomy has not been sufficiently discussed in the literature presumably because of the incomplete knowledge or confusing clinicopathologic explanations based entirely on organic or pathologic evidence. However, in view of the increasing knowledge being accumulated on the interrelationships of the circulatory system and its neurovascular components, namely, the sympathetic ganglions that arise at the various levels of the nervous system, it is only fitting that a better understanding of the functions of the sympathetic nervous system be set forth in a discussion of the treatment of this most distressing, disfiguring and, at times, dangerous complication.

In discussing the subject of surgical elephantiasis, especially that following mastectomy, Homans [1] stated that the swelling occurs in a freakish way and that an axillary dissection alone in the event of a mistaken diagnosis of cancer is capable of producing it, though not in its most serious form. In further discussion of the subject of reflex edemas he stated:

> The reflex edema represents a dysfunction of the nervous mechanism associated with the blood vessels. The little nerves of this mechanism, whether they are purely vasomotor and therefore sympathetic or sensory and therefore belong to the somatic nervous system, are carried on the blood vessels into the great nerve trunks, and consequently injuries of nerves as well as blood vessels may throw them into dysfunction.

From the Breast Tumor Section and the Neurosurgical Section, Bernard Fantus Clinics, Cook County Hospital, Chicago.

1. Homans, J.: Lymphedema of the Limbs, Arch. Surg. **40**:232 (Feb.) 1940.

It is obvious that the extensive dissections in the removal of a breast could account reflexly for some of the edema along the lines as stipulated by Homans.

Veal [2] has made an elaborate study of the venous circulation in patients with obstruction of the subclavian, axillary and basilic veins and has suggested that swelling of the arm is due to obstruction of the axillary and subclavian veins caused by thrombosis, scar formation and angulation of the veins and that lymphatic stasis is a secondary result of the venous obstruction, which if prolonged will lead to permanent blockage of the lymph flow. He states that "we then have a condition similar to the 'milk leg' which follows thrombosis of the deep veins of the thigh and pelvis. Infection is prone to develop after lymphatic and venous obstruction, and it may be the cause of further lymphatic blockage as well as an increase in the swelling."

Pure lymphatic edema is the least common form of edema following the removal of a breast, and the edema which is seen postoperatively in the swollen arm is really an admixture of venous obstruction, secondary lymph stasis and, apparently, a self-perpetuating mechanism depending on the tonicity of the muscles and the irritability of the various neurovascular elements associated in the involved area.

According to Leriche and Kumlin,[3] clinical manifestations in thrombophlebitis are due to the establishment of a vasomotor reflex as a result of impulses originating in the thrombosed venous segment. They are of the opinion that there are three dominant factors in this process: one, the amount of vein involved; two, arteriolar spasm, and three, venospasm. The last factor is the most constant and significant.

The frequency and extent of thrombophlebitis in the involved arm subsequent to mastectomy have never been ascertained. However, this is not so important, since the mechanisms operating at the site of the trauma are presumably the same in all instances in which the arm becomes swollen after mastectomy. Ochsner and DeBakey [4] were the first to call attention to the revolutionary teaching of Leriche and his associates that the mechanism of development of the clinical manifestations of thrombophlebitis is the initiation of a vasomotor reflex as a result of impulses originating in the thrombosed venous segment. They

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2. Veal, J. R.: The Pathological Basis for Swelling of the Arm Following Radical Amputation of the Breast, Surg., Gynec. & Obst. **67**:752, 1938.

3. Leriche, R., and Kumlin, J.: Tratamiento immediato de las flebitis, postoperatorias por la infiltracion novocainica del simpatico lumbar, Cron. med. mex. **33**:389, 1934.

4. Ochsner, A., and DeBakey, M.: Therapy of Phlebothrombosis and Thrombophlebitis, Arch. Surg. **40**:208 (Feb.) 1940; Thrombophlebitis: Role of Vasospasm in Production of Clinical Manifestations, J. A. M. A. **114**:117 (Jan. 13) 1940.

have shown by clinical and experimental observation that vasospasm resulting from impulses originating in the involved venous segment is one of the most important factors in the production of the symptoms. Such vasospastic influences affect both arterioles and venules. The mechanism by which vasospasm in thrombophlebitis can produce edema is dependent on the factors which result from vasospasm and an increase in the amount of the perivascular fluid. The factors are an increased filtration pressure, anoxia of the capillary endothelium and a diminution in the flow of lymph.

Ochsner and DeBakey have determined the venous pressure and have found it to be four or five times that in normal conditions. This increase in venous pressure obviously increases the filtration pressure, which favors transudation of the fluid from the vascular into the perivascular spaces. Because of the associated arteriolar spasm and evidences of diminished vascularity, there occurs a relative anoxia of the capillary endothelium favoring increased permeability of this membrane and consequent increased transudation of the vascular fluid into the perivascular spaces.

The edema is greatly influenced by the presence or absence of normal arteriolar pulsations, as has been demonstrated by McMaster and Parsons [5] and by Cressman and Blalock,[6] who showed that in the absence of pulsation there was no movement of lymph but that in the presence of pulsation the lymph flow was rapid. Monterio [7] has shown that the blocking of the sympathetic nerves increases the flow of lymph and furthermore that decrease in lymph flow results in stagnation of tissue fluids and accumulation of proteins in the perivascular fluid, thus setting up a vicious cycle tending to prevent resorption of the fluid from the perivascular spaces into the vascular tree.

Leriche and Kumlin and Ochsner and DeBakey have shown that the vicious cycle can be interrupted with paravertebral block (fig. 1).

Devenish and Jessop,[8] in their extensive clinical experiments, have failed to take cognizance of the fact that despite their astute observations on their cases they gave no consideration to the dysfunction of the various components of the sympathetic nervous system innervating the affected limbs that they describe. Consequently, despite their diver-

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5. McMaster, P. D., and Parsons, R. J.: Effect of the Pulse on the Spread of Substances Through Tissues, J. Exper. Med. **68**:377, 1938. Parsons, R. J., and McMaster, P. D.: Effect of Pulse upon the Formation and Flow of Lymph, ibid. **68**;353, 1938.

6. Cressman, R., and Blalock, A.: Effect of Pulse upon the Flow of Lymph, Proc. Soc. Exper. Biol. & Med. **41**:140, 1939.

7. Monterio, H., cited by Ochsner and DeBakey.[4]

8. Devenish, E. A., and Jessop, W. H. G.: Brit. J. Surg. **25**:261, 1937; **28**:222, 1940.

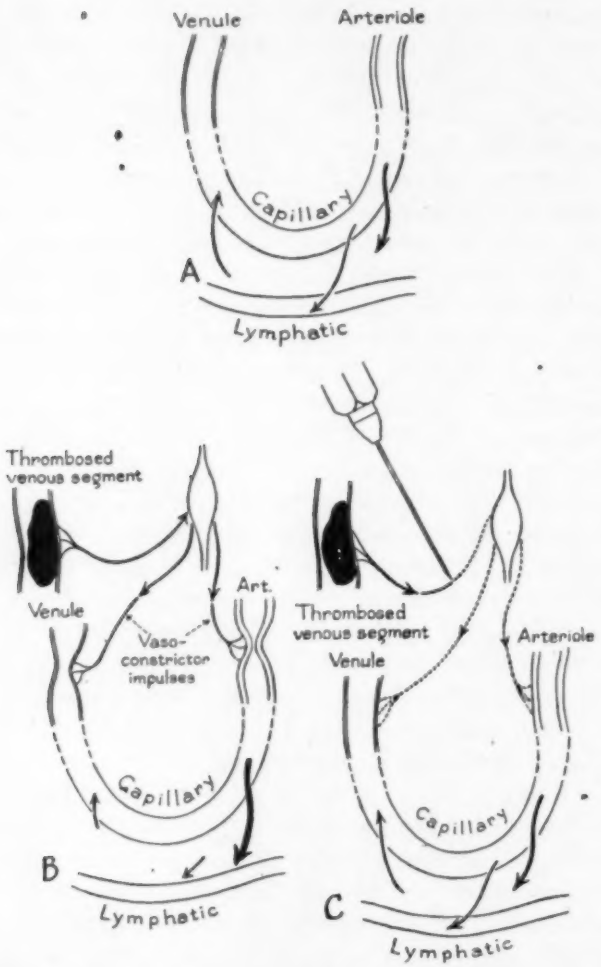

Fig. 1.—*A*, diagram of normal physiologic relationship of intravascular and perivascular fluids. As indicated by the arrows, normally there exists a balance between the amount of fluids leaving the blood vessels and entering the tissues and that leaving the tissues and entering blood and lymphatic vessels. (From Ochsner, A., and DeBakey, M.: J. A. M. A. **114**:117 [Jan. 13] 1940.) *B*, diagram of production of edema in thrombophlebitis. As shown by the arrows, the amount of fluids leaving the blood vessels and entering the tissues is greater than that leaving the tissues and entering the blood and lymphatic vessels. The increased transudation of fluids from the vascular system into the perivascular spaces is due to several factors. As a result of vasoconstrictor impulses initiated in the thrombosed venous segment there is produced a reflex vasospasm involving both the arteriolar and the venous elements of the vascular tree. Thus there occurs considerable increase in venous pressure, with consequent augmentation of filtration pressure and relative anoxia of capillary endothelium, both of which favor an increased transudation of vascular fluid into the perivascular tissues. The pronounced diminution of peripheral pulsations consequent to vasospasm and increased venous pressure results in a decrease in lymph flow and a stagnation of tissue fluids. (From Ochsner, A., and DeBakey, M.: J. A. M. A. **114**:117 [Jan. 13] 1940.) *C*, diagram of the mechanism by which procaine hydrochloride block

gence with Veal regarding some of his conclusions, it is only fitting to point out that the latter venographically demonstrated occlusions of the axillary and subclavian veins in more than 90 per cent of his cases. In view of the conclusions drawn by Leriche, Ochsner and DeBakey, McMaster and Parsons, Cressman and Blalock and Monterio, it would seem that Veal's work needed only slightly more intensive study to bring out the correlation between his findings of venous obstruction and the possibility that these obstructions were initiating and perpetuating a vicious cycle because of irritation of the peripheral end organs of the sympathetic nervous system in the thrombosed segment of the veins involved and that in applying the principles set forth by these authors it seemed only logical to perform a block of the sympathetic nerves in all cases of postoperative swelling of the arm following mastectomy.

CLINICAL MANIFESTATIONS

Clinically, the affected limb is in decided contrast to the limb on the side not operated on. The swelling is prominent, extends from the shoulder to the elbow (in some to the wrist) and may occasionally involve the hand. The skin, as a rule, is shiny and cold to touch, and it may have a so-called brawny induration. The movements of the arm are usually restricted because of the increased size, and subjectively pain is usually present. A sense of lifelessness at times is present, and the patients have difficulty in manipulating their fingers and doing fine movements of the hand. Elevation of the arm does help to eliminate some of the tension within the tissues, and the patients feel more comfortable. Periodically, some patients note that after a good night's rest the arm feels better, although after a short while recurrence of the bizarre sensations and impaired functions manifest themselves when the arm is held in a dependent position. However, not all the arms seen present the typical brawny induration, and a great many of them, though they are swollen, shiny and cold, have a flabby feeling more or less suggestive of excess adipose tissue. No evidence of distorted or dis-

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produces improvement in thrombophlebitic edema. Interruption of the vasoconstrictor impulses results in a decrease in venous pressure, increased vascularity and increased peripheral pulsations. The diminished venous pressure results in decreased filtration pressure and thus tends to prevent increased transudation of vascular fluid into the perivascular spaces. Increased vascularity reestablishes normal oxygenation of the vascular endothelium and permits return of normal permeability, which prohibits excessive transudation. Increased pulsations favor removal of perivascular fluids by increasing lymph flow. (From Ochsner, A., and DeBakey, M.: J. A. M. A. **114**:117 [Jan. 13] 1940.)

Thus it can be seen how the swollen arm after mastectomy is benefited by procaine hydrochloride block, which eliminates the vasoconstrictor elements which tend to perpetuate a vicious cycle of lymph stasis, excessive transudation, decreased vascularity and tissue anoxia.

tended veins is present, despite the fact that a great deal of the clinical picture may be secondary to obstruction of the venous flow.

Devenish and Jessop have shown that the superficial and deep lymphatic vessels can be brought out strikingly with the intradermal injection of an 11 per cent solution of a dye which they call patent blue V. In the normal arm after an injection of a minute amount of the dye intradermally distinct streamer formation is present, in contrast to the affected limb, in which no streamer formation is present with an extensive diffusion of the dye and the skin of the forearm becomes gradually discolored by a fine bluish network, giving the impression that the dye was seeping through a spongelike mass.

Temperature readings taken at various levels on the affected limb reveal that it is usually from one-half to one degree colder than the uninvolved arm. Measurements of the affected limb show an average increase of 1 inch (2.5 cm.) or more as compared with the uninvolved limb.

REPORT OF CASES

An analysis of 25 cases of postoperative swelling of the arm following mastectomy is herewith presented. Of the 25 patients involved, 21, or 85 per cent, had a block of the sympathetic nerves done on the affected side, 11 having it once, 5 having it twice, 2 having it three times and 4 having it four times. The number of times depended on the patient's ability to report for the procedure (factors being age, distance from the hospital and inclement weather). Both the anterior and the posterior approaches were used for the blocks; however, because of the multiplicity of minor complaints the posterior approach was abandoned, and the anterior or supraclavicular approach to the stellate ganglion was used exclusively.

A careful interrogation of the patient was made as to the onset of the symptoms subsequent to the mastectomy, whether or not she had preoperative or postoperative irradiation and whether or not any temperature or sensory disturbances were present in the arm before the operation. Careful measurements of the circumference of both arms were made 5 inches (12 cm.) above and 5 inches below the olecranon process. Dermatherm readings were made for both arms and all corrections for room temperature carefully recorded.

IMMEDIATE EFFECT OF THE PARAVERTEBRAL BLOCK

Subsequent to the injection of 5 cc. of a 1 per cent solution of procaine hydrochloride into the stellate ganglion on the affected side, 20, or 96 per cent, of the patients noted an immediate feeling of warmth in the arm, and the average rise in temperature as demonstrated by the dermatherm readings was 4 degrees. Increased flexibility, relief of pain and a decrease in paresthesia and hypesthesia were noted in all instances.

SUBSEQUENT EFFECTS OF THE PARAVERTEBRAL BLOCK

The persistence of the subjective improvement was noted in 80 per cent of the patients. Subjectively, the feeling of warmth was manifested in all but 1 of them. The greatest improvement was noted in those who had two or more injections.

There was a pronounced disparity between the subjective improvement and the objective temperature readings and the reduction in the size of the arm after the paravertebral block. In 10, or 47 per cent, of the patients who had block there was no reduction in the measurements. Eleven, or 53 per cent, manifested only an average reduction of three fourths of an inch (2 cm.), which, however, in itself is insignificant since 80 per cent showed persistent improved flexibility, increase in temperature, and improved motion of the affected limb. The rises in temperature noted represent readings taken from two to seven days after the block. This is interesting because it supports the contention of Leriche and Kumlin that the responses of the temperature are at times out of proportion to the amount of procaine hydrochloride used and that the persistent response can sometimes be obtained with minimal doses of the drug. That the manifested persistent temperature response appears small is probably due to the insulating effect of the edema and the tissue fibrosis, which tends to inhibit the response.

The patient's impression of the type of therapy used is worthy of comment, since the satisfaction of the patient is an indication of the success of the treatment. Nineteen, or 90 per cent, reported that they were benefited by the treatment. One patient (5 per cent) was guarded in her comment; however, she did say that the response was fair. Another patient was noncommittal in her response despite the fact that some objective improvement was present.

Of the 4 control patients who did not have a paravertebral block and who were observed for the same period (six months), none exhibited any improvement of the arm as compared with those who had it one or more times (table).

SUMMARY AND CONCLUSIONS

The injection into the stellate ganglion of 5 cc. of a 1 per cent solution of procaine hydrochloride at periodic intervals will help to relieve the symptoms referable to swelling of the arm following mastectomy.

Over 80 per cent of the patients treated revealed subjective and objective clinical improvement after the paravertebral block.

Sixty per cent manifested an average reduction of three fourths of an inch (2 cm.) in the size of the involved extremity.

No improvement was noted in patients who did not have paravertebral block.

Analysis of Twenty-Five Cases of Postoperative Swelling of the Arm Following Mastectomy

	Subjective Response					Objective Response				
Case	No. of Times Block Was Done	Feeling of Warmth	Relief of Pain	Flexibility	Sensory Improvement	Dermatherm Reading Persistent Temperature Response, Degrees	Tactile Temperature Improvement	Reduction in Measurement, Inches	Improvement in Motion	Patients' Impression of Treatment
1	3	++++	++++	++++	++++	2	++++	½	++++	Successful
2	2	++++	++++	++++	++++	1½	+++	½	++++	Successful
3	1	++++	++++	++++	+++	1	++	0	++++	Successful
4	2	++++	++++	++++	++++	1	++	½	++++	Successful
5	4	++++	++++	++++	+++	1	++	0	+++	Successful
6	1	++++	++++	++++	++++	1	++	0	++	Successful
7	4	++++	++++	++++	+++	2	++++	0	+++	Successful
8	2	++++	++++	++++	++++	1	++	0	+++	Successful
9	2	++++	++++	++++	++++	1	++	1	++++	Successful
10	1	++++	++++	++++	++++	1	++	1	++++	Successful
11	3	++++	++++	++++	++++	1½	+++	0	++++	Successful
12	1	++++	++++	++++	++++	1½	+++	1	++++	Successful
13	1	++++	++++	++++	++++	1	++	1	++++	Successful
14	1	++++	++++	++++	++++	1	++	0	++++	Successful
15	1	++++	++++	++	++	1	++	½	+++	Fair
16	1	++++	++++	++++	++++	1	++	0	+++	Noncommittal
17	2	++++	++++	++++	++++	1	++	½	++++	Successful
18	4	++++	++++	++++	++++	1	++	1½	++++	Successful
19	1	+++	++	++	+	0	+	0	+	Not successful
20	1	0	0	0	0	½	+	0	0	Not successful
21	1	++++	++	++++	++	½	+	0	+	Not successful
22	0	0	0	0	0	0	0	0	0	.....
23	0	0	0	0	0	0	0	0	0	.....
24	0	0	0	0	0	0	0	0	0	.....
25	0	0	0	0	0	0	0	0	0	.....

The improvement of the circulation and the mobility of the involved arm subsequent to the paravertebral block are definite steps forward, since the treatment heretofore of this distressing clinical entity has been more or less unsuccessful. This may be due to the fact that more effort was being expended in trying to reduce the swelling of the arm than in trying to increase its usefulness. A simple application of physiologic principles of the sympathetic nervous system will relieve the subjective and objective symptoms in over 80 per cent of cases.

As has been shown, the clinical improvement demonstrated is dependent to a great extent on the number of times paravertebral block is carried out; the more frequent the block, the more persistent and prolonged the response. We have speculated on the advisability of doing sympathectomies for permanent reversal of this phlebospastic state, and suitable cases for this procedure are at present being studied.

19 Madison Street, Oak Park, Ill. (Dr. Sol M. Wolffson).

NEUROVASCULAR SYNDROME OF THE ARM ASSOCIATED WITH HYPERTROPHIED SUBCLAVIUS MUSCLE

Report of a Case, Including Operative Treatment

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DYSFUNCTION of an upper extremity due to pressure on vascular and nerve elements in the region of the shoulder are not uncommon and are extremely disabling. The scalenus anticus syndrome is well recognized and is frequently treated surgically with good result. The syndrome of thrombosis of the axillary vein is perhaps less well recognized, and its treatment is commonly entirely conservative in nature. It may be present with or without actual thrombosis. Various functional and mechanical factors have been suggested as of etiologic significance. Perhaps the most commonly accepted opinions have implicated the structures in the area of the clavicle and first rib (Aschoff,[1] Löhr,[2] Willan,[3] Loewenstein,[4] Gould and Patey,[5] Picagli,[6] Veal and McFetridge,[7] Sampson and others [8] and Judovich and others [9]).

1. Aschoff, L.: Thrombose und Embolie, Verhandl. d. gesellsch. deutsch. Naturf. u. Aerzte **83**:344, 1916.

2. Löhr, W.: Ueber die sogenannte "Traumatische" Thrombos der Vena axillaris und subclavia, Deutsche Ztschr. f. Chir. **214**:263, 1929.

3. Willan, R. J.: Three Cases of Axillary Vein Obstruction, Edinburgh M. J. **20**:105, 1918.

4. Loewenstein, P. S.: Thrombosis of the Axillary Vein: An Anatomic Study, J. A. M. A. **82**:854 (March 15) 1924.

5. Gould, E. P., and Patey, D. M.: Primary Thrombosis of the Axillary Vein: A Study of Eight Cases, Brit. J. Surg. **16**:208, 1928.

6. Picagli, G.: Trombosi da sforzo della vena ascellare destra, Chir. d. org. di movimento **19**:186, 1934.

7. Veal, J. R., and McFetridge, E. M.: Primary Thrombosis of the Axillary Vein: An Anatomic and Roentgenologic Study of Certain Etiologic Factors and a Consideration of Venography as a Diagnostic Measure, Arch. Surg. **31**:271 (Aug.) 1935.

8. Sampson, J. J.; Saunders, J. B. de C. M., and Capp, C. S.: Compression of the Subclavian Vein by the First Rib and Clavicle, with Special Reference to the Prominence of the Chest Veins as a Sign of Collateral Circulation, Am. Heart J. **19**:292, 1940.

9. Judovich, B.; Bates, W., and Brayton, W.: Pain in the Shoulder and Upper Extremity Due to Scalenus Anticus Syndrome, Am. J. Surg. **63**:377, 1944.

The symptoms in the case reported here simulated those of both syndromes, and in fact the diagnosis of scalenus anticus syndrome was made on several occasions in different institutions and was suggested by neurosurgical consultants at the Wakeman General Hospital. The obstruction actually found was present in the area between the clavicle and the first rib, which is mentioned by most writers. Because of the unusual interest aroused and the unexplained result from an apparently previously unreported operative procedure, the case was considered worthy of being reported. The preoperative data, unfortunately, are incomplete, lacking records of venous pressures, which have been shown to be elevated in similar cases, as well as records of the mechanical temperature and the oscillometric readings. However, the clinical findings as recorded by several observers, including orthopedic, neurologic and general surgeons and a neurologist as well as consultants from outside the hospital, were so cleancut that they are considered adequate.

REPORT OF CASE

A 35 year old soldier was admitted to Wakeman General Hospital from an Army Station Hospital on April 7, 1945. The following history was obtained from the patient and later confirmed by records of previous hospitalization. On Dec. 25, 1940 he received an injury to his shoulder and was knocked unconscious in an automobile accident. He was treated at the Levi Hospital in Hot Springs, Ark., for one and one-half days. Roentgenograms were said to have shown a fractured clavicle. Further treatment was carried out by an orthopedist, who said that the patient had a fractured clavicle and treated him in bed with the shoulders strapped back and with a pillow between them. About five days after the injury, the patient's hand became swollen, edematous and cyanotic. This was thought to be due to the bandages. The bandages were cut, without relief, and the hand began to get numb and to tingle on the eighth day. The swelling decreased over a period of a month, and the condition was considered cured. However, he could not lift his arm to an angle above 90 degrees without discomfort, and even at that level the arm would soon weaken and begin to drop. He could not stand pressure on the left shoulder or lie on it without discomfort. The numbness, tingling and pain continued, with only short periods of relief obtained when he would hold the arm up by the elbow.

He was inducted into the army on July 20, 1942, but was unable to carry a pack, and when he started on extended order drill he was able to continue for five days only because of continuous aching in the whole arm and in the shoulder. There were numbness and tingling in the whole hand and a decrease of strength to such a degree that he would even drop a cup of coffee. The symptoms remained almost continuously despite repeated hospitalization from July 1942 until his admission to Wakeman General Hospital on April 7, 1945; three attempts at limited duty failed because of weakness, pain and discomfort in the arm with any attempt to use it.

Repeated examinations had been made in other institutions, and the preferred diagnosis was scalenus anticus syndrome. In repeated examinations at the Wakeman General Hospital by neurologists, neurosurgeons and orthopedists the following observations were consistently made. The general physical condition was essentially normal. The patient was lean and wiry but had well developed

muscles, especially about the shoulders. There was moderate dilatation of the veins of the left arm and shoulder. The left hand and forearm became cyanotic when the arm was dependent, with the cyanosis most pronounced on the hand and wrist and shading off to a fairly normal color above the elbow. The left hand was definitely colder than the right. With elevation, the cyanosis slowly disappeared in three to five minutes and the hand and arm blanched more and more and remained cold. There was definite weakness of the left arm and hand (60 to 75 per cent) as compared with the right. The patient was able to elevate the arm just to an angle of 90 degrees but was unable to hold it there for more than a few seconds. It then slowly and steadily fell despite evident effort. There was slight palpable prominence of the sternal end of the clavicle, with a small notch at the junction of the shaft and the sternal enlargement. The radial pulse was of good quality but was completely obliterated with elevation of the arm to an angle of 40 degrees. It then again gradually became apparent at an elevation of about

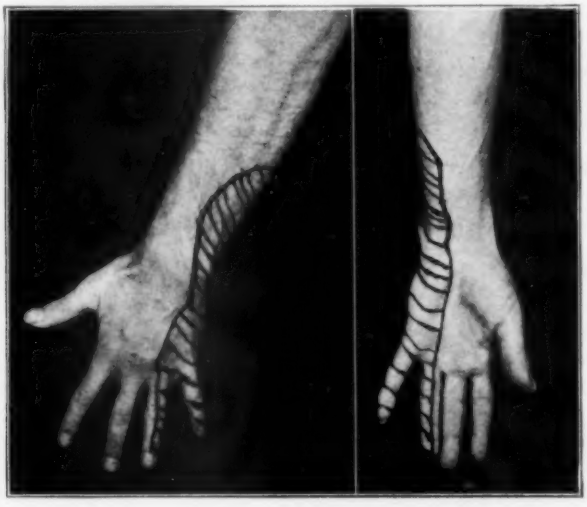

Fig. 1.—Photograph of the area of hypesthesia conforming well to ulnar distribution.

70 degrees, but was obliterated at an elevation of 90 degrees. There was definite hypesthesia in the ulnar distribution of the hand (fig. 1).

Venographic studies were performed, 20 cc. of "diodrast" being used. Roentgenograms were taken after injection of 10 and 20 cc. and fifteen seconds after completion of the injection. Because of the complete block still present a fourth one was taken, approximately ten minutes after the development of the previous three. This showed a complete obstruction still present, with moderate collateral filling of the veins (fig. 2).

Operative Report and Postoperative Course.—On May 30, 1945, a modified incision was made for exploration of the brachial plexus (fig. 3) with the use of local anesthesia. As the fascia over the deltopectoral groove was incised it was noted that the cephalic vein was markedly distended. As it was followed upward to its point of transit through the coracoclavicular fascia, it was noted that there were two definite bulbous dilatations, which were evidently proximal to valves in the vein. The coracoclavicular fascia was incised, without any evident release of

the pressure. In order to expose the clavicle, the origin of the pectoralis major muscle was separated subperiosteally from the clavicle. The cephalic vein was found to pass between the edges of the pectoralis minor and subclavius muscles to empty into the subclavian vein, which was also found to be markely distended. As the dissection was carried out, an enlarged subclavius muscle, appearing to be two to three times the usual size (about 3.0 cm. in diameter) rolled up from beneath the clavicle as though squeezed out under pressure. As the subclavius rolled outward it was noted that distention of the cephalic and axillary veins was released. The brachial plexus, the subclavian and axillary arteries and the subclavian and axillary veins were carefully explored from well above the clavicle to below the point of insertion of the pectoralis major, and no other unusual condition was noted. With the subclavius muscle out from beneath the clavicle, it was possible to insert the index finger between the clavicle and the first rib and the vein and artery filled and emptied normally. With the muscle in its normal position, it was possible to get only the tip of the fifth finger between it and the rib and distention of the vein became apparent.

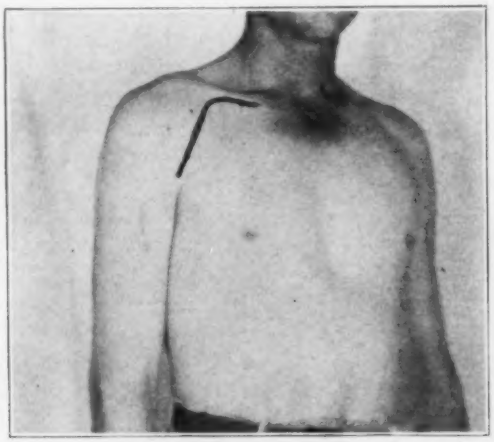

Fig. 2.—Incision outline. This is not the patient in the case under consideration, but the incision is an exact replica of the one made therein.

The sternoclavicular joint was then explored. There was posterior displacement of the clavicle to about 3 mm. Elevation of this was considered but it was not performed. The subclavius muscle was incised at the point at which the vein passed beneath it, and the edge of the muscle was sutured to the anterior periosteum of the clavicle to keep it from being pushed back beneath the clavicle. (A segment of muscle should have been removed for better clearance and for pathologic examination.) The fascia only of the pectoralis major was sutured to the periosteum at the anterior edge of the clavicle.

The patient's postoperative course was surprisingly satisfactory. Within twenty-four hours he stated that the arm was improved, but it was thought that this was due to the support of the arm by the bandages and sling. However, after removal of all support the relief continued. For the first two weeks the hand still became slightly cyanotic when dependent, but the veins were no longer distended and the patient had discomfort for only a few minutes on two occasions. By this time he was able to lie on the involved side without discomfort.

A venogram was made on the seventeenth postoperative day. Care was taken to have the arm in the same position as at the previous examination. At this examination there was no obstruction fifteen seconds after cessation of injection (fig. 4).

The first realization that a good result was to be expected came when, on return from a pass, the patient proudly exhibited his left thumb swollen from fracture of the metacarpal induced when he struck an opponent with the involved fist on the seventeenth postoperative day. His statement was that at no time during the four years since injury had he been able to get his arm up and strike with it, let alone do it quickly enough so that his opponent was unable to duck or hard enough

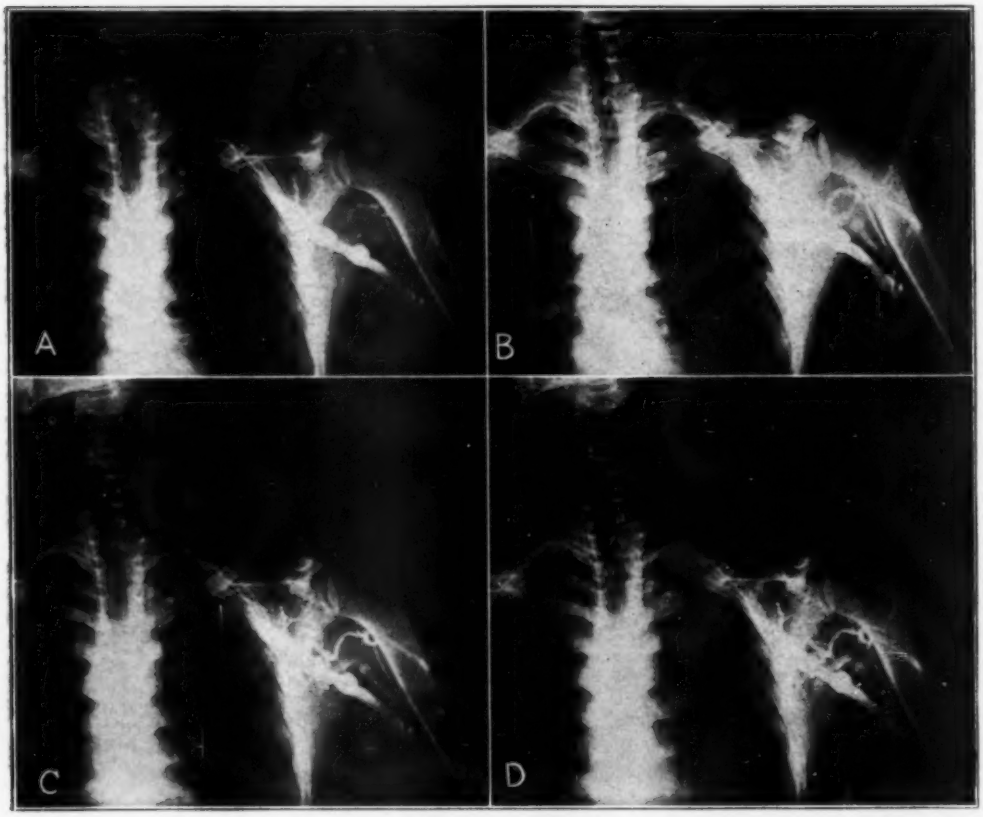

Fig. 3.—Preoperative venogram. *A*, after injection of 10 cc. of "diodrast." *B*, after injection of 20 cc. of "diodrast." *C*, fifteen seconds after cessation of injection. *D*, ten minutes (approximately) after cessation of injection.

to make an impression. He was given a thirty day furlough, and on his return the condition of the hand and arm was about the same. He stated that he had had pain for a few minutes only on one or two occasions during the furlough.

Final examination was made before his discharge from the hospital five months after operation. The veins were not distended, and the hand and forearm no longer became cyanotic. The pulse was no longer obliterated on elevation of the arm. There was no difference in the temperature of the two upper extremities. The left hand and arm did not blanch on elevation. The strength of the left

extremity had definitely increased, and it was now 85 to 90 per cent as strong as the right extremity. He could raise the arm to an angle of above 140 degrees and could maintain it at an angle of 90 degrees for more than ten minutes. The prominence of the sternal end of the clavicle remained. Sensation was normal in the hand. These findings were checked by the men in each specialty, except for the consultants, who had made the preoperative examination. A third venogram, made just before discharge of the patient, failed to show obstruction. The patient was again examined in June 1946 and in January 1947. He is now working as a clerk, and the only difficulty encountered has been in placing or moving heavy articles on shelves high above the head when it is done repeatedly without rest. The condition has remained the same as it was at the time of discharge.

COMMENT

Thrombosis of the axillary vein has been reported and the symptomatology carefully described repeatedly since the first credited report

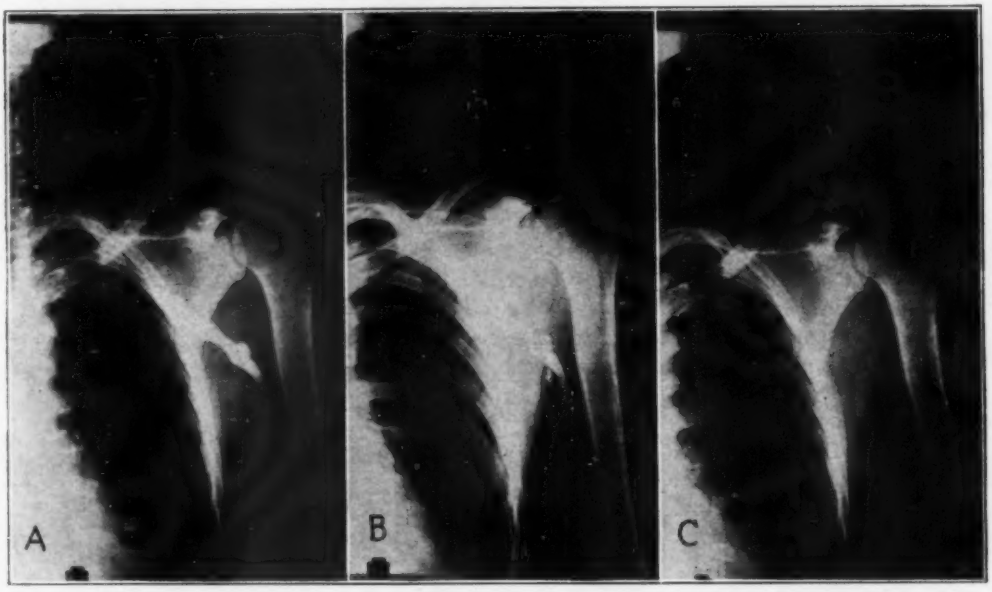

Fig. 4.—Postoperative venogram. *A*, after injection of 10 cc. of "diodrast." *B*, after injection of 20 cc. of "diodrast." *C*, fifteen seconds after cessation of injection.

by Von Schrotter.[10] Excellent reviews and case reports have been given by Willan,[8] Matas,[11] Veal[12] and others. Although the mor-

10. von Schrotter: Erkrankungen der Gefässe, in von Nothnagel, H.: Specielle Pathologie und Therapie, Vienna, Alfred Hölder, 1894, vol. 15, pt. 3, p. 533.

11. Matas, R.: Primary Thrombosis of the Axillary Vein Caused by Strain, Am. J. Surg. **24**:642, 1934.

12. Veal, J. R.: (*a*) Thrombosis of the Axillary and Subclavian Veins, Am. J. M. Sc. **200**:*27*, 1940; (*b*) Thrombosis of the Axillary and Subclavian Veins with a Note on the Post-Thrombotic Syndrome, Am. Heart J. **19**:*292*, 1940.

tality from this disease is minimal, the morbidity is a serious factor, especially since in the majority of cases it occurs in men who do relatively heavy work and are bread-winners. The early loss of time from work with an acute attack may be prolonged for weeks to months or even years with the chronic state. Individual cases in which there has been prolonged disability have been reported by Jeanneny and Mathey-Cornat,[13] Baum,[14] Firth and Mackay,[15] Mason,[16] McGoogan and Simmons,[17] McClanahan,[18] Clute,[19] Ballon,[20] Swindt[21] and Anderson.[22]

In an excellent discussion of the entire problem Matas[11] reported a case followed for four years in which there was residual disability. Gould and Patey[5] reported on 8 cases, of which 5 were followed. Four of the 5 patients had persistent symptoms of varying severity, 1 having them for six months, 1 for four years, 1 for five years and 1 for an unstated length of time after onset of the disease. The fifth patient reported no complaints. Veal[12b] followed 7 of 9 cases of phlebothrombosis and thrombophlebitis of the axillary vein for two months to twenty-two years. All the patients involved had weakness, early fatigue and pain after prolonged work or exercise.

Although in many instances actual thrombosis of the vein has been shown to be present (Paggi,[23] Guyot and Jeanneny,[24] Grimault and

13. Jeanneny G., and Mathey-Cornat, R.: Thrombo-phlebite dite par effort du membre superieur, J. de méd. de Bordeaux **101**:858, 1924.

14. Baum, H. L.: Die traumatische Venenthrombose an der oberen Extremität, Deutsche med. Wchnschr. **39**:997, 1913.

15. Firth, D., and Mackay, R.: Primary Thrombosis of the Axillary Vein with Recurrence, Lancet **2**:679,1932.

16. Mason, J. M.: Clinics: Primary Thrombosis of the Axillary Vein Caused by Strain, Internat. Clin. **1**:239, 1938.

17. McGoogan, T. S., and Simmons, E. E.: Effort Thrombosis of the Subclavian Vein in the Puerperium, Nebraska M. J. **18**:283, 1933.

18. McClanahan, B. V.: Primary Thrombosis of the Axillary Vein, Am. J. Surg. **30**:459, 1935.

19. Clute, H. M.: Idiopathic Thrombosis of the Axillary Vein, S. Clin. North America **11**:253, 1931.

20. Ballo, H. C.: Primary Thrombosis of the Axillary Vein, Canad. M. A. J. **32**:414, 1935.

21. Swindt, J. K.: Traumatic Thrombosis of the Upper Extremities, California & West. Med. **27**:635, 1927.

22. Anderson, O.: Venography in Case of So-Called Traumatic Thrombosis of Axillary Vein, Acta radiol. **19**:126, 1938.

23. Paggi, B.: Trombosi venose da sforzo degli arti superiori, Policlinico (sez. chir.) **40**:383, 1933.

24. Guyot, J., and Jeanneny, G.: Thrombo-phlebite dite "par effort" de la veine axillaire: Examen anatomopathologique (Sabrazes), Bull. et mém. Soc. de chir. de Paris **49**:231, 1923.

Dantlo,[25] Chifoliau and Folliasson,[26] Huard [27] and Lapeyre [28]), in others the same syndrome has been present without thrombosis (Moure and Martin,[29] Cottalorda,[30] Löhr [2] and Hammann [31]). The mechanism responsible in the cases without thrombosis has usually been considered to be spasm secondary to trauma. The presence of this syndrome with or without actual thrombosis has been attributed to many factors. Von Schrotter [10] considered it to be due to stretching of the axillary vein, while Cadenat [32] felt that distention of the vein by respiratory effort was responsible. However, pressure of various structures in the area about the clavicle and the first rib has been most frequently suggested as the causative factor (Aschoff,[1] Löhr,[2] Loewenstein,[4] Gould and Patey,[5] Picagli,[6] Veal,[12] Veal and McFetridge,[7] Sampson and others [8] and Judovich and others [9]). Willan [3] suggested that the vein suffered injury against the first rib and that the intima was damaged, which determined the occurrence of a thrombus. Loewenstein [4] believed that the pressure by the costocoracoid ligament and subclavius muscle on the axillary vein distended by the forced expiration which characterizes effort resulted in venous stasis. His excellent drawings of anatomic dissections of the shoulder area show these pressure points with various positions of the arm. Picagli [6] likewise felt that the syndrome was due to the anatomic relations in the region of the costocoracoid ligament. Sampson, Sanders and Capp [8] suggested that the compression of the subclavian vein occurred between the first rib and the clavicle and that this pressure was increased by the subclavius muscle and the deltopectoral fascia. They furnished convincing evidence to support their additional contention that this was more likely to occur in a special structural type, i. e., persons with high, horizontally curved first ribs and with the clavicle directed upward and backward. More recently,

25. Grimault, L., and Dantlo, R.: Thrombo-phlébite dite "par effort" de la veine axillaire, Presse méd. **5**:10, 1924.

26. Chifoliau, M. T., and Folliasson, A.: Thrombo-phlébite a streptocoques du membre superieur droit: Guérison rapide par resection segmentaire de la veine axillaire thrombose, Presse méd. **40**:84, 1932.

27. Huard, P.: Thrombo-phlébite du membre superieur gauche revelee par un effort: Resection du segment veineux thrombose; denudation arterielle, Presse méd. **42**:556, 1934; Bull. et mém. Soc. nat. de chir. **59**:1406, 1933.

28. Lapeyre, J. L.: A propos de la thrombo-phlebite dite par effort, Rev. de chir. **52**:229, 1933.

29. Moure, P., and Martin, R. H.: Apropose de la thrombo-phlebite par effort, Presse méd. **20**:371, 1932.

30. Cottalorda, J.: La thrombo-phlebite par effort, Lyon chir. **29**:169, 1932.

31. Hammann, W.: Zur Kenntnis der sogenannten Achselvenenthrombose (Claudicatic venosa intermittens der oberen Extremität), Zentralbl. f. Chir. **67**: 1871, 1940.

32. Cadenat, F. M.: Les thrombophlebite du membre superieur, Paris méd. **35**:253, 1920.

Wright [33] has also implicated these structures and also the subscapularis muscle and has supported his opinion with anatomic dissections.

The most convincing evidence that pressure points are involved has been furnished by those workers who used injection methods. Gould and Patey,[5] using cadavers, injected plaster of paris into the cubital veins with the arm abducted. In 1 instance a shallow groove corresponding to the costocoracoid ligament was shown and in 2 others a broad deep groove corresponding to the subclavius muscles. Injection studies on living patients for various purposes have shown similar defects. Sampson,[34] during an injection with "diodrast" for visualization of the heart, obtained roentgenograms which showed a defect of a like nature just proximal to the first rib. He also reported a similar observation by Robb and Steinberg,[35] in whose patient, incidentally, the typical syndrome of thrombosis of the axillary vein developed after the injection as though to add emphasis to the findings. In studies of this particular area Veal and McFetridge [7] observed the same defect, which they considered to be due to pressure of the subclavius muscle.

The possibility that there is a close anatomic relationship between the scalenus anticus syndrome and the syndrome of obstruction of the axillary vein has been considered by Veal [12a] and by Judovich and others.[9] They suggested that both may be caused by spasm of the scalenus anticus muscle, which, according to the latter, draws up and holds the first rib so as to compress the artery, vein and nerves against the subclavius muscle and the clavicle. Judovich and his colleagues reported on 2 patients with dilatation of the veins of the shoulders and arms, 1 of whom at operation had dilatation of the vein lateral to the first rib. One patient had symptoms for two years and the other for fifteen years, and both showed gradual improvement after section of the scalenus anticus muscle. The cases of Falconer and Weddell,[36] discussed later, might also be considered to be in this category.

In the presently recorded case the flow of opaque medium was found to stop at a point just lateral to the clavicle and first rib, and the obstruction was practically complete, with much filling of collateral veins. This is the usual position of obstruction, the second commonest region being in the area of the subscapularis tendon. At exploration the obstruction was shown to be due to narrowing of the space between the clavicle and the wall of the chest. This narrowing, it was felt,

33. Wright, I. S.: Neurovascular Syndrome Produced by Hyperabduction of Arms, Am. Heart J. **29**:1, 1945.

34. Sampson, J. J.: An Apparent Causal Mechanism of Primary Thrombosis of the Axillary and Subclavian Veins, Am. Heart J. **25**:313, 1943.

35. Robb, G. P., and Steinberg, I., cited by Sampson.[34]

36. Falconer, M. A., and Weddell, G.: Costo-Clavicular Compression of the Subclavian Artery and Vein: Relation to the Scalenus Anticus Syndrome, Lancet **2**:539, 1943.

was due to hypertrophy of the subclavius muscle plus slight posterior displacement of the clavicle as a result of the original injury. The deltopectoral and costocoracoid ligaments, which many authors have considered to be of importance in this syndrome, were not shown to have any real significance in the present case.

Treatment of the syndrome of obstruction of the axillary vein has been largely conservative, with rest and elevation during the acute stage and suggestion of change of occupation for the post-thrombotic syndrome. This has not been entirely satisfactory because of the great loss of time from work and the fact that many persons with this syndrome are unable to get work requiring less effort. In a few cases surgical treatment has been undertaken. Cures have been reported by thrombectomy or by excision of a segment of the vein in the acute stages. Paggi [23] found and excised the thrombotic portion in 28 cases, with good result. Stabins [37] more recently has reported a good early result from ligation and resection of the axillary vein. Other cases in which excision of the thrombotic segment was carried out have been reported by Guyot and Jeanneny,[24] Grimault and Dantlo,[25] Chifoliau and Folliasson,[26] Huard,[27] and LaPeyre.[28] Moure and Martin [29] reported a cure after exploration in a case in which they found no thrombus or actual occlusion but rather a collection of serum and edema in the area of the injury. Cottalorda [30] reported a cure by exploration in a case in which there was no thrombus but in which the vein was in a state of rigid spasm. Ochsner and DeBakey [38] reported 2 cases in which cure was effected by sympathetic block.

In the presently reported case there was no thrombosis shown at operation, and as a result resection was not considered. Since it was a late case, mere exploration could not be expected to give a satisfactory result. However, a simple procedure, i. e., section of the subclavius muscle to relieve the pressure on the vein, artery and nerves, gave a satisfactory result. It is hoped that in future cases the syndrome may be treated by similar simple procedures in order to improve the known serious morbidity of this condition. It would seem reasonable to suspect that if the operation were carried out early, before permanent fixation of secondary responses, the results might be satisfactory. Sympathetic block should first be tried in early cases because of its simplicity and the good results obtained by Ochsner and DeBakey.[38]

Falconer and Weddell [36] treated several patients with scalenus-anticus-like syndrome with compression of the subclavian artery and vein. In the first case a segment of the first rib was removed from beneath the

37. Stabins, S. J.: Primary Thrombosis of the Axillary Vein Due to Strain, U. S. Nav. M. Bull. **41**:1106, 1943.

38. Ochsner, A., and DeBakey, M.: Therapy of Phlebothrombosis and Thrombophlebitis, Arch. Surg. **40**:208 (Feb.) 1940.

artery, with excellent result. In the second case a cervical rib was present. The scalenus anticus muscle was first incised, but there was still pressure on the lower cord. The tip of the cervical rib was then removed, but pressure remained although it was lessened. In the third case compression of the lower trunk of the brachial plexus against the first rib by a tendinous band was revealed, which was relieved by section of the band.

It is possible that in the occasional case of scalenus anticus syndrome in which cure is not brought about by section of the scalenus anticus muscle there may be a syndrome present similar to that in these cases and in the presently reported one. Differentiation could be made first by observation of the evidences of venous pressure, although in an occasional case the vein passes over the insertion of the scalenus anticus and could be compressed (Gray [39] and Judovich and others [9]), second by injection of procaine hydrochloride into the scalenus anticus, as suggested by Falconer and Weddell [36] and Judovich and his colleagues, and third by careful observation at operation of the involved structures and the extremity before and after section of the scalenus anticus muscle.

CONCLUSIONS

The syndrome of so-called thrombosis of the axillary vein is of importance because of the serious morbidity.

It is likely that a predisposing cause lies in an unusual anatomic relationship, with narrowing of the costoclavicular space, and/or enlargement and hypertrophy of the subclavius muscle and hypertrophy of the costoclavicular fascia or, in some instances, of the subscapularis muscle.

Diagnosis is made by observance of the typical symptoms and signs and by venographic study, which gives a typical picture of obstruction of the flow of opaque medium usually in the region of the clavicle and first rib and of filling of collateral channels.

Treatment has been conservative in most instances. Operation is believed to be justified in a larger number of cases in view of its relative simplicity and the consistently good results reported.

A case of so-called post-thrombotic syndrome is reported in which considerable improvement followed the relief of pressure by section of the subclavius muscle.

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39. Gray, H.: Anatomy of the Human Body, ed. 24, Philadelphia, Lea & Febiger, 1942, p. 665.

PRECAUTIONARY ADMINISTRATION OF PENICILLIN IN SURGICAL PROCEDURES ON BONES AND JOINTS

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AND
JOHN E. BLAIR, Ph.D.
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DURING the course of a project [1] on the use of penicillin in the treatment of chronic osteomyelitis, recommended by the Committee on Medical Research and contracted for by the office of Scientific Research and Development with the Hospital for Joint Diseases, the opportunity arose for the initiation and the subsequent development of several collateral studies. All these were briefly discussed in the report [2] submitted at the official termination of the project, and others [3] were subsequently reported with additional data in greater detail. This paper concerns itself with the use of penicillin as a precautionary measure against infection during the course of surgical procedures with primary closures of the wounds of bones and joints on (1) patients without osteomyelitic lesions, (2) patients with inactive osteomyelitic lesions, (3) patients with active infections and (4) patients with postoperative infections. These studies were closely coordinated with studies on the bacteriologic status of the wounds and the penicillin concentration in the blood and urine.

PENICILLIN IN SURGICAL PROCEDURES ON NONOSTEOMYELITIC PATIENTS

At the onset of the project, when the supply of penicillin was limited, the drug was used only in the treatment of clean surgical wounds when the operative field became contaminated or when the patient was subjected to undue trauma. In those instances 20,000 units of penicillin was administered intramuscularly every three hours immediately after

1. Buchman, J., and Blair, J. E.: Penicillin in the Treatment of Chronic Osteomyelitis: A Preliminary Report, Arch. Surg. **51**:81-92 (Sept.) 1945.

2. Buchman, J., and Blair, J. E.: Report on the Use of Penicillin in the Treatment of Staphylococcal Infections with Special Reference to Acute and Chronic Osteomyelitis and Several Collateral Studies, Bull. Hosp. Joint Dis. **6**:114-125 (Oct.) 1945.

3. Blair, J. E.; Carr, M., and Buchman, J.: The Action of Penicillin on Staphylococci, J. Immunol. **52**:281-292 (Nov.) 1946. Buchman, J., and Blair, J. E.: The Use of Absorbable Substances to Obliterate Bone Cavities and as Hemostatic Agents in Bone and Joint Conditions, J. Bone & Joint Surg., to be published.

TABLE 1.—*Administration of Penicillin in Surgical Procedures on Patients Who Did Not Have Osteomyelitis*

Case	Comment
1	Exploration for herniated nucleus pulposus and Hibb's fusion of the lumbosacral area of the spine reenforced by tibial "clothespin" graft; operative field contaminated by oil leaking from motor saw; healed per primam
2	Open repair of extensively comminuted fracture of patella; patient aged and in poor general condition with unexplained fever and comminuted fracture of shoulder; postoperative pneumonia and stormy convalescence; healed per primam
3	Open reduction of pathologic (marble bone) fracture of shaft of femur and fixation with Townsend-Gilfillan plate; healed per primam
4	Open reduction and fixation with Thompson Z nail of extensively comminuted intertrochanteric fracture of neck of femur; subjected to severe surgical trauma; spontaneous drainage of sterile hematoma on 14th postoperative day; complicated by phlebitis of internal saphenous vein; healed on 40th day
5	Open reduction of dislocation of elbow and fracture of neck of radius subsequent to severe trauma incidental to manipulation on two occasions under anesthesia and complicated by unexplained rise in temperature; healed per primam
6	Interinnominoabdominal amputation for osteogenic sarcoma superimposed on Paget's disease of pelvis with obstruction of rectum and urethra; complicated by postoperative slough of part of flap away from incision due to embarrassed circulation; incision healed per primam
7	Interinnominoabdominal amputation for recurrent osteogenic sarcoma of stump of thigh; healed per primam save for slough of flap as in case 6
8	Excision of epiphysial plate of neck of femur for epiphyseolysis and unsuccessful attempt at nailing with Thompson Z nail; healed per primam
9	Open dislocation of malaligned head and neck of femur, with replacement of head and fixation with ivory peg; healed per primam (same patient as in case 8)
10	Intra-articular arthrodesis and fixation of hip with 2 Thompson Z nails for osteoarthritis; healed per primam
11	Inlay tibial bone graft for fixation of symphysis pubis for disruption of pelvis incidental to parturition; healed per primam
12	Translocation osteotomy and fixation with reverse Neufeld nail for ununited fracture of neck of femur; no plaster of paris immobilization; patient was turned on opposite side on 1st postoperative day, and operative site was completely disrupted; skin sutures held; healed per primam
13	Nail removed and parts realined and immobilized in plaster of paris spica; shaft slipped; healed per primam (same patient as in case 12)
14	Fracture site (hip) exposed, parts realined and fixed with stainless steel screws and immobilized in plaster; nonunion occurred; healed per primam (same patient as in case 13)
15	Colonna reconstruction operation; healed per primam (same patient as in case 14)
16	Arthroplasty of hip for osteochondritis dissecans; healed per primam
17	Interscapulothoracic amputation for sarcoma of coracoid process; healed per primam
18	Prolonged exposure of forearm for repair of nerves because of causalgia and paralysis of hand; repair could not be performed; healed per primam
19	Amputation through forearm; healed per primam (same patient as in case 18)
20	Repair of ulnar nerve and tendon—3½ hours; healed per primam
21	Biceps femoris transplantation; healed per primam
22	Triple arthrodesis of foot and transplantation of peroneus longus tendon; healed per primam (same patient as in case 21)
23	Synovectomy of knee for chronic hydroarthrosis; healed per primam
24	Secondary arthrotomy of knee for excision of scar from osteochondritis dissecans, chondromalacic areas of patella and femur and internal semilunar cartilage; healed per primam
25	Arthrotomy of knee completely disorganized from an old infection for removal of loose bodies, semilunar cartilages and exostoses; healed per primam
26	Arthrotomy of knee for removal of discoid meniscus and parameniscal cyst; healed per primam
27	Biopsy and disarticulation of hip for osteogenic sarcoma; healed per primam save for small areas of skin necrosis due to embarrassed circulation
28	Excision of comminuted head of radius and capitellum; healed per primam
29	Open reduction and fixation of humerus with Townsend-Gilfillan plate; healed per primam
30	Open reduction and fixation of fracture of neck of femur with Thompson Z nail following recovery from lobar pneumonia; healed per primam
31	Translocation osteotomy of femur and fixation with reverse Neufeld nail for ununited fracture of neck of femur; healed per primam
32	Excision of fractured olecranon and fixation of triceps tendon; healed per primam
33	Arthroplasty of hip and insertion of vitallium head and neck prosthesis for Marie-Strümpell disease; healed per primam
34	Obturator nerve resection; healed per primam (same patient as in case 33)
35	Open reduction of comminuted intertrochanteric fracture of neck of femur and fixation with Neufeld nail; healed per primam
36	Intra-articular and extra-articular arthrodesis of hip for poliomyelitis; healed per primam save for 2 small stitch abscesses
37	Intra-articular and extra-articular arthrodesis of Charcot hip and fixation with Thompson Z nail; healed per primam
38	Translocation osteotomy and fixation with reverse Neufeld nail for Charcot hip; healed per primam (same patient as in case 37)
39	Open lengthening of right tendo achillis for spastic paralysis; healed per primam
40	Open lengthening of left tendo achillis for spastic paralysis; healed per primam (same patient as in case 39)

the operation and for about ten days thereafter. As the supply of the antibiotic became less limited, it was administered to patients undergoing extensive operative procedures in which a complicating infection would have been disastrous. When the supply of the drug became plentiful, its administration was extended to practically all patients undergoing operative procedures. The technic evolved consists of the intramuscular administration of 20,000 units of penicillin every three hours day and night for twenty-four hours before the surgical procedure and for ten days thereafter. At the termination of the operative procedure, as each layer of tissue is sutured, the wound is flooded with an isotonic solution of sodium chloride containing 250 units of penicillin per cubic centimeter of the solution. Gauze soaked in the same solution is used for a dressing over the wound.

Table 1 lists all the operative procedures, forty-one in number, which have been performed under the conditions just described. Not a single infection occurred in this series notwithstanding the fact that in some instances there were actual contaminations of the field of operation, in others there were undue traumas before, during or after the operation, in others the procedures were unduly prolonged and in still others the procedures were of great magnitude. The only wound which broke down (case 4) was incidental to a large hematoma which was sterile. In several instances flaps or edges of skin underwent necrosis because of impaired circulation rather than because of infection.

It would therefore appear, in view of the complete avoidance of infections in the series of cases presented in table 1, that the intramuscular administration of penicillin for twenty-four hours before an operative procedure on bones and joints and for about ten days after and the local application of penicillin to the operative wound constitute a dependable method for the avoidance of the ordinary surgical infections which have plagued patients and embarrassed surgeons from time to time.

PENICILLIN IN SURGICAL PROCEDURES ON PATIENTS WITH INACTIVE OSTEOMYELITIS

Surgical procedures were performed on patients who had been subject to chronic osteomyelitic lesions of long standing, many of them multiple in distribution. All the lesions were apparently inactive at the time of the performance of the operations listed in table 2. Nevertheless, we would have deferred most of these procedures because of the history of relatively recent activity in all these instances were it not for the use of penicillin. In none of these instances was there any flare-up of the preexisting infections. The regimen consisted of the intramuscular administration of 20,000 units of penicillin every three hours for twenty-four hours preceding the operation and for approximately ten days thereafter. In addition, 250 units of penicillin per cubic centimeter of

isotonic solution of sodium chloride was used to flood the wound during the various stages of closure. None of the wounds was drained.

Though the series of instances is limited in number, it would nevertheless appear from the experiences with these patients and with those to be described in the next section that surgical procedures, with closure of the wounds, may be performed without the fear of recurrence of recent infections when the procedures are carried out under antibiotic control.

PENICILLIN IN SURGICAL PROCEDURES ON PATIENTS WITH ACTIVE INFECTIONS

The previously reported demonstration [4] of the high frequency of healing by primary intention of extensively saucerized chronic osteomyelitic

TABLE 2.—*Administration of Penicillin in Surgical Procedures on Patients with Inactive Osteomyelitis*

Case	Comment
1	Excision of scar and skin plastic for recurrent ulcerations of scar of tibia incidental to saucerization operation; healed per primam
2	Excision of scar and translocation of fibula for nonunion of tibia secondary to infected compound fracture; healed per primam
3	Excision of spur of os calcis at site of a previous saucerization for chronic osteomyelitis; healed per primam
4	Vitallium cup arthroplasty of left hip for ankylosis in a patient with multiple quiescent osteomyelitic lesions; healed per primam
5	Vitallium cup arthroplasty of right hip for ankylosis in the presence of multiple quiescent osteomyelitis lesions; healed per primam (same patient as in case 4)
6	Resection of the left obturator nerve and removal of exostosis of malleolus which was the site of an osteomyelitic lesion; healed per primam (same patient as in case 4)
7	Resection of the right obturator nerve; healed per primam (same patient as in case 4)
8	Quadricepsplasty for limitation of motion incidental to long-standing chronic osteomyelitis; healed per primam

wounds treated under penicillin control has led us to perform surgical procedures with primary closures and without drainage notwithstanding the presence of active infection elsewhere in the body, whether the infection is distant or in close proximity to the operative site. The technic evolved consists of the use of 20,000 units of penicillin intramuscularly every three hours for twenty-four hours before and ten days after the operation and 250 units of penicillin per cubic centimeter of isotonic solution of sodium chloride to flood the operative wound at the various stages of closure without drainage. Gauze soaked in the penicillin-sodium chloride solution is used as a dressing for the wound. In instances in which the invading organisms are resistant, correspondingly larger doses of penicillin are utilized intramuscularly and locally. In none of the cases reported in table 3 have the secondary invaders ("nuisance organisms"), even though they were resistant to penicillin, interfered with the healing by primary intention.

4. Buchman and Blair (footnotes 1 and 2).

A review of table 3 indicates that convalescence was greatly shortened in that operative procedures were not postponed until infections elsewhere in the body were eliminated. Secondary operative closures have been eliminated through the avoidance of guillotine amputations, and the

TABLE 3.—*Use of Penicillin in Surgical Procedures on Patients with Active Infections*

Case	Comment
1	Callander amputation with primary closure and rubber tissue drain for an extensive osteomyelitis of the tibia and fibula with lymphedema and circumferential ulceration of the lower half of the leg; flaps in close proximity to ulceration; healed per primam
2	Resection of the fifth toe and distal two thirds of the fifth metatarsal bone and closure of the wound without drainage for osteomyelitis in a diabetic patient; healed per primam
3	Resection of the third and fourth toes and distal portion of the third metatarsal bone for perforating ulcers under third toe and third metatarsal in a diabetic patient; previous operative site (case 2) well healed; healed per primam
4	Amputation of the middle part of the forearm through edematous area containing many thrombosed vessels and primary closure with silkworm gut drain for gangrene subsequent to operative reduction of a dislocated shoulder in the presence of persistent drainage from the shoulder wound; healed per primam; several small superficial areas of necrosis of the skin developed; final healing in 136 days, but elbow joint, which in other circumstances would have been sacrificed, was preserved
5	Amputation through junction of middle and upper thirds of leg with primary closure for chronic osteomyelitis of tibia and large indolent ulcer; anterior flap bordered on ulcer; healed per primam; by primary closure a possible loss of the knee joint or at best an inadequately short stump was avoided
6	Arthrotomy of the left knee for the removal of para-articular and intra-articular osteocartilagenous bodies and an intra-articular exostosis which left a large dead space in the presence of an infected ulcer on the right leg; healed per primam
7	Resection of the third toe and metatarsal bone for chronic osteomyelitis; healed per primam
8	Amputation through midportion of proximal phalanx of index finger for gangrene which followed self treatment; skin flaps bordered on gangrenous area; healed per primam, making possible the preservation of a useful stump
9	Arthrodesis of hip for congenital dislocation in the presence of a draining sinus at site of the Steinmann pin in lower end of the same femur; healed per primam
10	Amputation of the midleg through the site of a previously active chronic osteomyelitis of long duration and an adherent scar with the flaps bordering on a persistent ulcer; healed per primam save for a small area of dry necrosis over site of old scar
11	Skin plastic and shortening of stump (1.5 cm.) for recurrent ulceration of 10 months' duration from irritation of prosthesis over atrophic skin; healed per primam; preservation of an effective stump below the knee would not have been contemplated without antibiotic control (same patient as in case 11)
12	Amputation of the left midcalf for tuberculosis of foot with large open wound; healed per primam
13	Amputation of the right midcalf for tuberculosis of lower 2 inches of the fibula, ankle joint and os calcis with sinuses and swelling above the ankle joint; healed per primam
14	Amputation of the midcalf for chronic osteomyelitis of tibia with large ulcer over lower third of leg and circumferential trophic disturbance of skin; flaps bordered on ulcer; healed per primam (same patient as in case 13)
15	Neurolysis of musculospinal nerve and open reduction of fracture of midportion of humerus and fixation with a Townsend-Gilfillan plate in the presence of a pressure sore with a necrotic base over anterior aspect of the elbow on the same side; healed per primam
16	Lukas shelf operation for pathologic dislocation of hip subsequent to destruction of head and neck of femur in the presence of a roentgenographically active though clinically quiescent osteomyelitic lesion in the upper half of the same femur; healed per primam
17	Callander amputation for spreading gangrene of the forefoot in an 86 year old patient with arteriosclerosis complicated by diabetes; healed per primam

possibility of the performance of the ablations, with primary closure and without drainage, in close proximity to the site of disease has made possible the preservation of neighboring joints, which otherwise would have of necessity been sacrificed.

PENICILLIN IN POSTOPERATIVE INFECTIONS OF BONES AND JOINTS

The group of cases presented in table 4 is limited in number and represents an accumulation over three and one-half years. Four of the patients were operated on by other surgeons. A review of these cases reveals no encouraging evidence pointing to the effectiveness of penicillin as the sole mode of therapy in the treatment of the postoperative infections described. In the first 4 cases the patients were treated in the days when the penicillin supply was greatly limited, and they may therefore possibly be excluded from consideration on the ground that the dosage was inadequate and that the length of therapy was insufficient. The remaining patients, on the other hand, were treated with adequate amounts of the antibiotic over a sufficient period.

In case 5 a penicillin-resistant organism was present, which would have required a blood level of penicillin not obtainable in ordinary circumstances. The flooding of the operative wound with a concentration of 250 units of penicillin would in all probability have been more than sufficient to prevent the development of the infection in that case. In 2 of the remaining cases the lesions contained penicillin-sensitive organisms. The clinical courses of these lesions were not different from those of lesions in which the sensitivities of the organisms were not determined. One may therefore conclude that the resistance of the organism to the influence of the antibiotic is not the deciding factor in the ineffectiveness of the drug under the given conditions.

The failure of penicillin as the sole mode of therapy to modify the course of the postoperative infection is readily understandable if one takes into consideration the inherent nature of the lesion. It is similar to the usual "surgical infection" in contrast to the "medical infection." The latter is characterized by an inflammatory process, with little or no necrosis of tissues. The lesion therefore remains in communication, or even may be in closer communication, with the blood stream because of the increased blood supply to the part and may therefore be influenced by therapeutic agents within the stream. A "surgical infection," on the other hand, is characterized by an inflammatory process on which there is superimposed multiple thrombotic phenomena, necrosis, suppuration and a walling-off process which greatly diminishes and eventually shuts off the blood supply to the local lesion so that therapeutic agents contained within the blood stream may become ineffective because of inability to reach the lesion. In the early phases of the surgical infection, before the tissues become thrombosed and necrotic, penicillin therapy may be effective. From these considerations it becomes evident that the timing of the administration of penicillin is the crux of the situation.

The early phases of postoperative infection presumably occur at the time of the surgical procedure and soon thereafter, when no appreciable

TABLE 4.—*Use of Penicillin in Postoperative Infections of Bones and Joints*

Case	Comment
1 and 2	A severe postoperative infection following Hibb's fusion of the lumbosacral area of the spine with a double "clothespin" tibial bone graft associated with pneumonia and bacteremia caused by coagulase-positive Staphylococcus aureus, with subsequent break-down of both wounds, was treated with 60,000 units of penicillin daily intravenously for 5 days and 12,500 units in daily local dressings. Treatment was started on the 12th postoperative day, when the bacteremia had already subsided. No appreciable effect could be noted from the use of a total of 362,500 units of penicillin.
3	An infection subsequent to a Wagner posterior bone block of the foot was found on the 10th postoperative day, and culture revealed coagulase-positive Staph. aureus and secondary invaders; administration of 20,000 units of penicillin every three hours intramuscularly and daily local application of 250 units per cubic centimeter of isotonic solution of sodium chloride were started on the same day. The total amount of penicillin used was 590,000 units. The temperature did not subside until the wound was drained. The subsequent course did not demonstrate any beneficial effect from the use of penicillin.
4	An infection arose after Hibb's fusion of the lumbosacral area of the spine reenforced by tibial bone grafts. Coagulase-positive Staph. aureus was cultured from the blood and the operative wound (spine). The intravenous administration of 150,000 units of penicillin daily and the local application of 250 units per cubic centimeter of sodium chloride solution were started on the 8th postoperative day, when the blood was already sterile. A total of 681,000 units was administered without any appreciable effect on the clinical course.
5	An infection incidental to an open reduction of a fracture on the neck of the femur and fixation with a Thompson Z nail was noted on the 10th postoperative day; the wound was opened, penicillin was applied locally and an immediate dose of 40,000 units was administered intramuscularly This was followed by doses of 20,000 units given every 3 hours and daily local applications of 250 units per cubic centimeter of sodium chloride solution. The wound yielded coagulase-positive Staph. aureus and secondary invaders; the Staph. aureus was found to be resistant to 3.0 units of penicillin and was destroyed by 6.0 units, while the blood concentration was only 0.312 unit. Sulfathiazole was therefore given by mouth in addition to the penicillin. The temperature continued to go up to 104 F., and chills occurred on the 17th, 19th and 20th postoperative days. The blood culture continued to reveal organisms till the 25th postoperative day. Thereafter the temperature began to drop to more normal levels, and on the 29th day the blood culture was sterile. Penicillin to the amount of 3,460,000 units was administered intramuscularly over a period of 23 days in addition to the local application of the drug; 86 Gm. of sulfathiazole was administered over a period of 15 of the 23 days, and several transfusions were given. Penicillin alone and the reenforcement with sulfathiazole did not seem to have any influence on the course of infection, and the patient continued to have a persistent sinus and nonunion The nail was extruded during the course of the infection.
6	After arthroplasty for an ankylosed hip incidental to Marie-Strümpell disease and immobilization in a plaster of paris spica for 18 days, during which the highest temperature was 100 F., a pronounced rise in temperature developed subsequent to the removal of the spica. Repeated examinations and aspirations of the operative site failed to reveal any infection. On the 27th postoperative day an area of redness was noted; this was probed, and pus was encountered and evacuated. The area was flooded with isotonic solution of sodium chloride containing 250 units of penicillin per cubic centimeter, and intramuscular administration of 20,000 units of the drug every 3 hours was started immediately. Neither the temperature nor the discharge was controlled till the wound was opened under general anesthesia and the limb reimmobilized in a plaster of paris spica. A second exploration, with removal of diseased bone, flooding of the wound with penicillin and closure without drainage in association with the preoperative and postoperative administration of penicillin intramuscularly, finally resulted in healing. The primary administration of 1,480,000 units of penicillin at the onset of the infection was totally ineffective.
7	Prior to the performance of an intra-articular arthrodesis of a hip and its fixation with a Thompson Z nail, 100,000 units of penicillin was administered in 5 doses. For some unexplained reason the operative wound was not flooded with penicillin, nor was the postoperative intramuscular administration of penicillin carried out. A culture from the operative field was sterile. On the 5th postoperative day the patient was found to have a streptococcic dermatophytosis of one hand. A moderate rise in temperature persisted. The wound was dressed on the 8th day, and a slight sanguineous discharge was noted. A culture revealed a coagulase-positive Staph. aureus sensitive to 0.078 unit of penicillin and secondary invaders. The discharge persisted and increased. Local and systemic penicillin therapy was started on the 13th postoperative day, and a total of 2,600,000 units was administered over a period of 17 days without any influence whatsoever on the infection. After a period of 2 months the wound and sinus were subjected to a thorough debridement, flooded with penicillin and closed without drainage in conjunction with the preoperative and postoperative administration of 20,000 units of penicillin intramuscularly every 3 hours. The wound healed in 20 days.
8	On the 6th day after an arthrodesis of a flail knee incidental to poliomyelitis and its fixation with a Townsend-Gilfillan plate and a plaster of paris cylinder the patient's temperature rose to 102.6 F. The plaster bandage was bivalved, and a purulohemorrhagic discharge was encountered. Systemic and local applications of penicillin were started immediately. During the following 4 days, the temperature gradually subsided. A number of sinuses developed, and pus was drained. After a period of 40 days, all wounds healed. A total of 2,180,000 units of penicillin was administered over a period of 14 days. The effect on the wound is dubious. The infective organism was a coagulase-positive Staph. aureus sensitive to 0.01 unit of penicillin.
9	The start of systemic and local applications of penicillin on the 6th day after an operation for a fracture of the neck of the femur and its fixation with a Thompson Z nail in a 70 year old woman suffering from chronic rheumatoid arthritis and pernicious anemia, with a fluctuating temperature and local evidence of infection, failed to produce a favorable influence on the clinical course. The wound broke down and drained copiously. After a period of 9 days the temperature subsided, and the use of penicillin was discontinued. Ten days later the systemic administration of 30,000 units of penicillin was started again. Seven days thereafter the temperature began to increase and metastatic foci developed in the ipsilateral knee and contralateral ankle. Large quantities of penicillin were used, without any appreciable effect on the course of the disease.

clinical signs are present to indicate the presence of an infection. In view of this, penicillin therapy if it is to be effective must be started before the evidences of the infection are clinically apparent, that is, at the time of the operative procedure. That this reasoning is correct is indicated by the data presented in tables 1 and 2 on a series of 48 patients subjected to a large variety of operative procedures under varying conditions of preoperative, operative and postoperative trauma without a single gross postoperative infection.

CONCLUSIONS

In view of the foregoing observations it seems reasonable to draw the following conclusions:

1. Penicillin, as the sole agent of therapy, is ineffective in the control of postoperative infections in surgical procedures on bones and joints unless it is administered during the earliest phases of infection, that is, at the time of operation or soon thereafter. This ineffectiveness refers only to the local lesion and not to the systemic lesion (bacteremia), if it should be present.

2. The precautionary antibiotic control of surgical procedures, with primary closure, on bones and joints is an effective method for the prevention of postoperative infections. This consists of the preoperative and postoperative intramuscular administration of adequate doses of penicillin and the flooding of the operative wound at the time of closure without drainage with a penicillin-sodium chloride solution of adequate concentration.

3. The precautionary antibiotic control of surgical procedures, with primary closure without drainage, on bones and joints in persons with quiescent osteomyelitic lesions, regardless of the period of quiescence, is an effective method for the prevention of the flare-up of these infections.

4. The precautionary antibiotic control of surgical procedures, with primary closures without drainage, on bones and joints in the presence of active infection, be it in close proximity or at a distance, is an effective method of obtaining healing of the operative wounds by primary intention. This technic makes possible the shortening of convalescence, the avoidance of secondary operative procedures and in certain instances of amputation the saving of the proximal joint.

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